THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

JANUARY 1956

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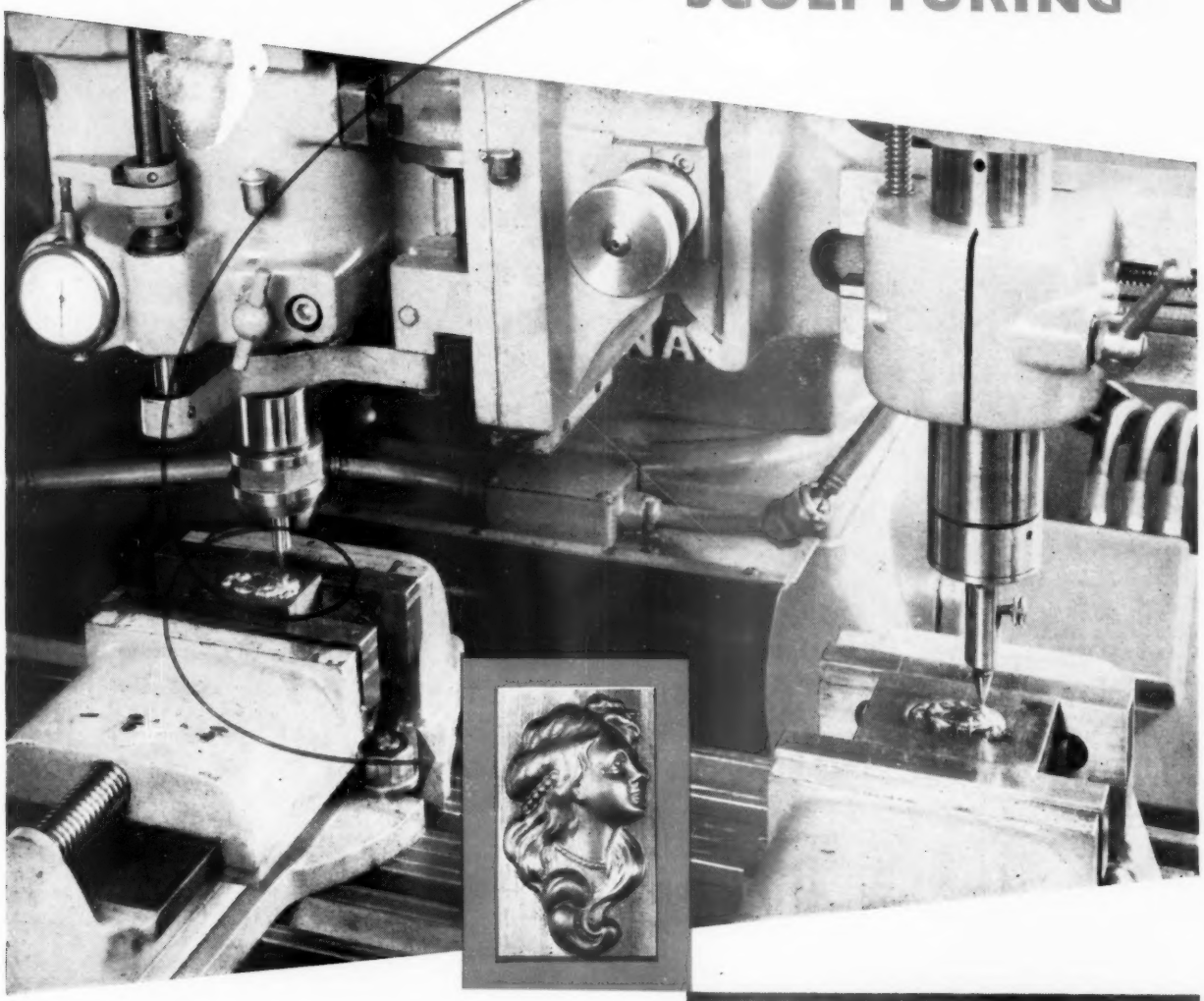

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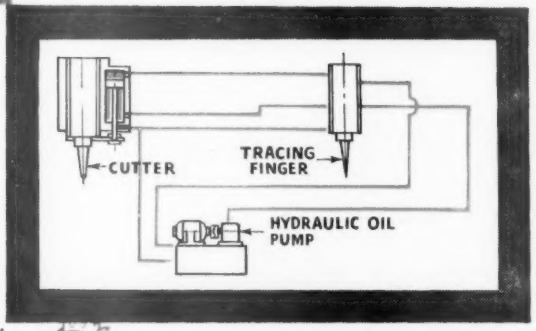

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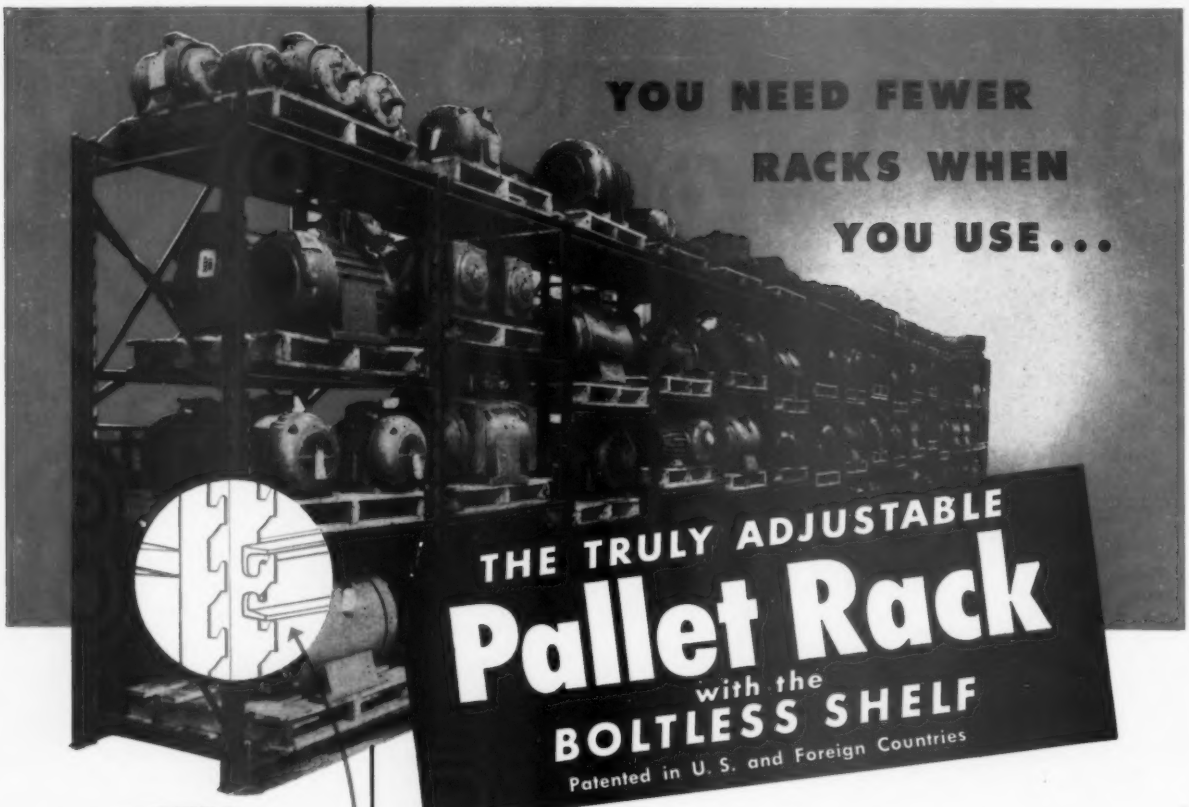

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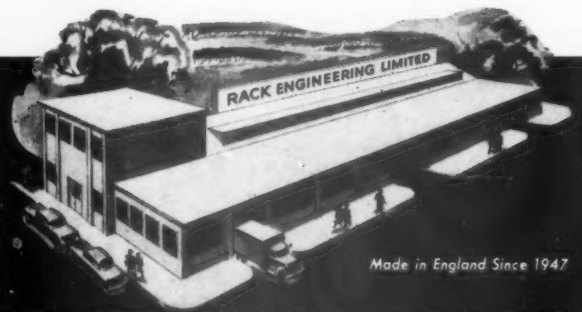

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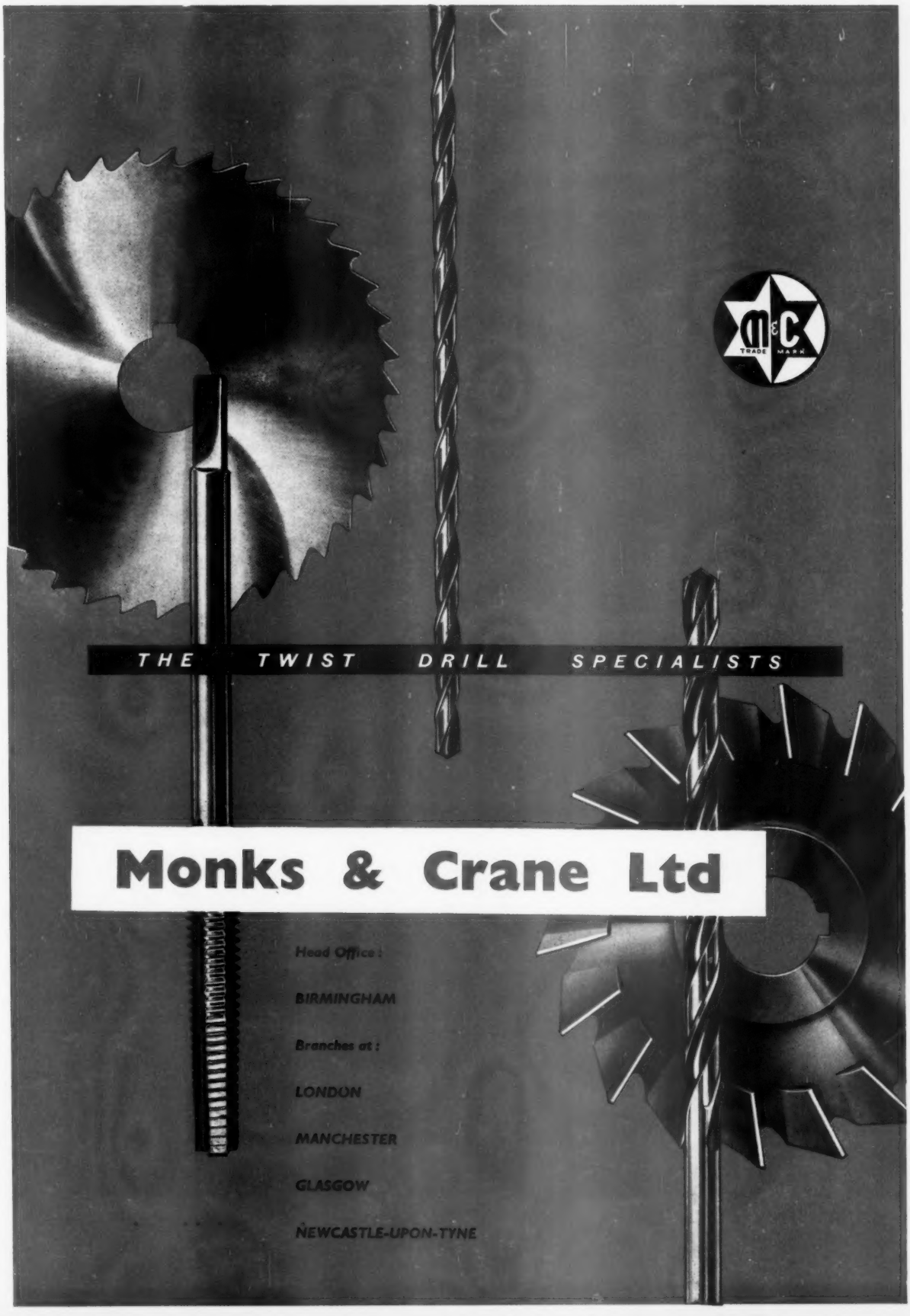
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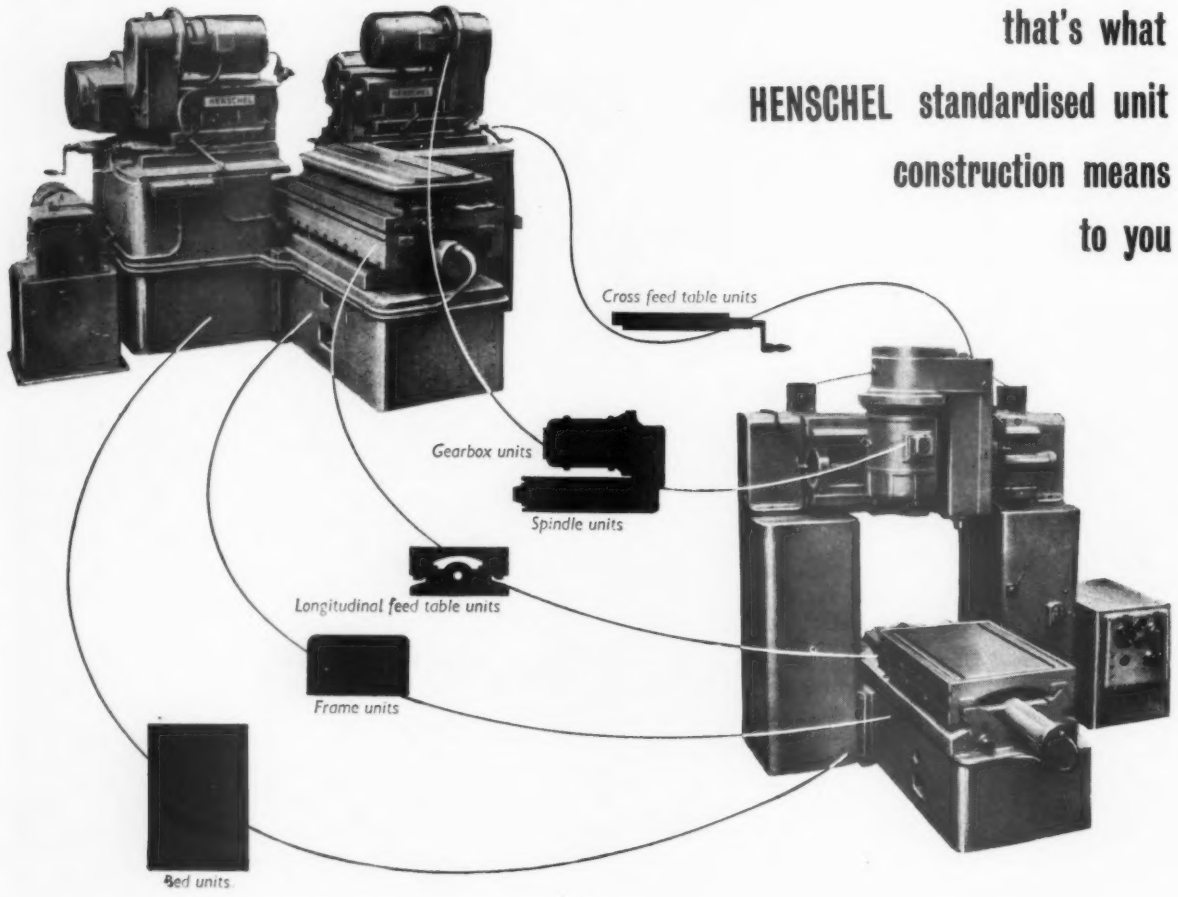

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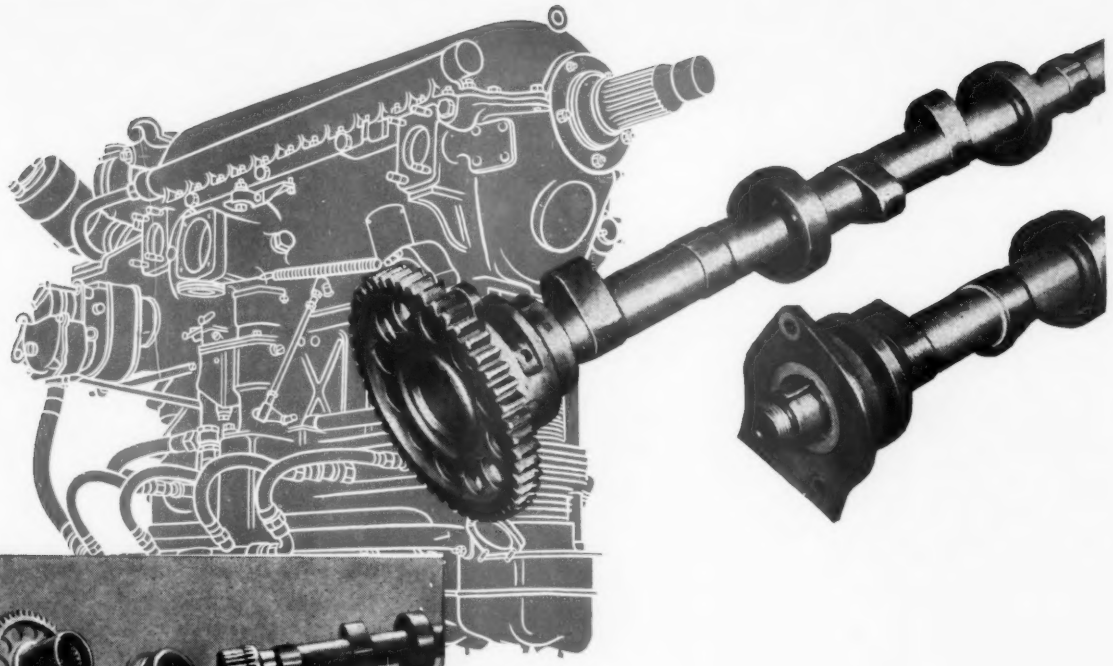

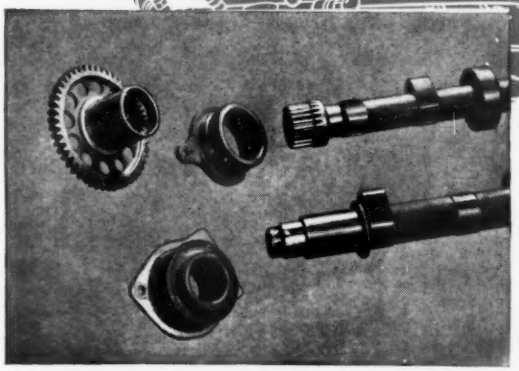

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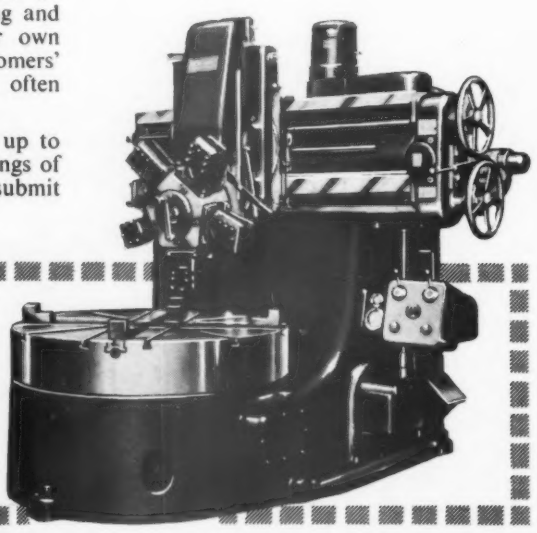

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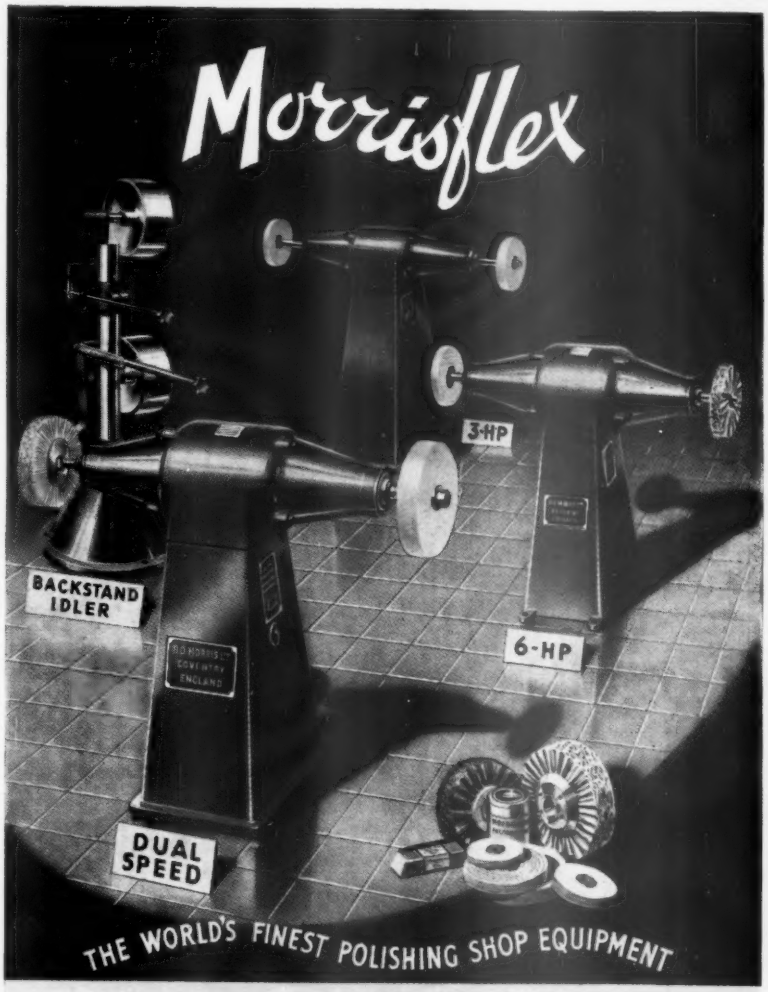

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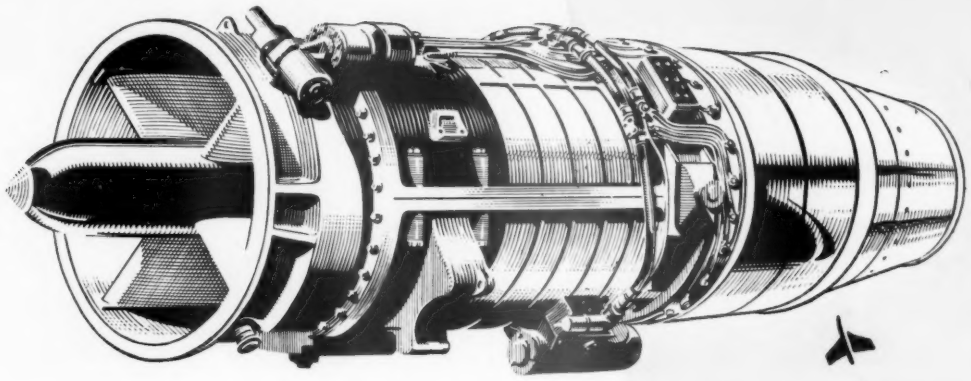

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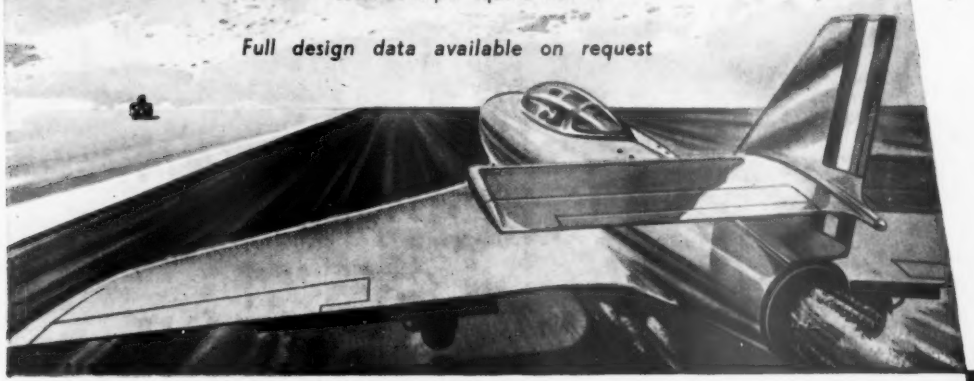

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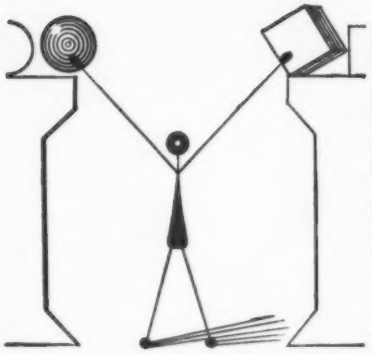
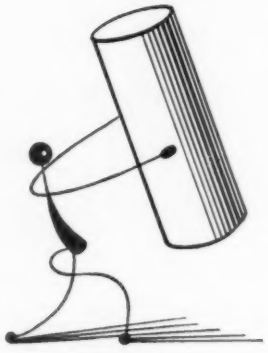
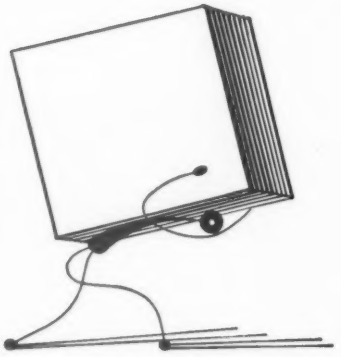


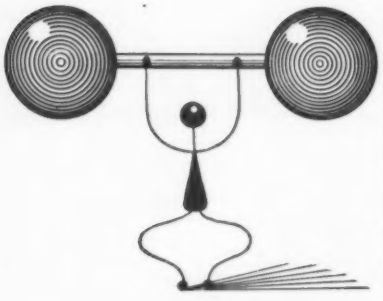
...reach...



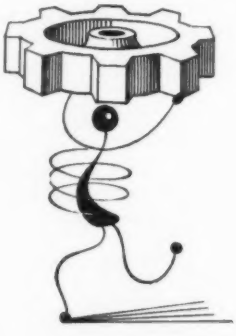
...grasp...



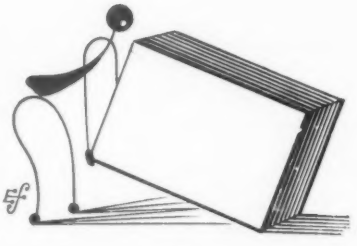
...carry...



...lift...



...turn...



...tilt...

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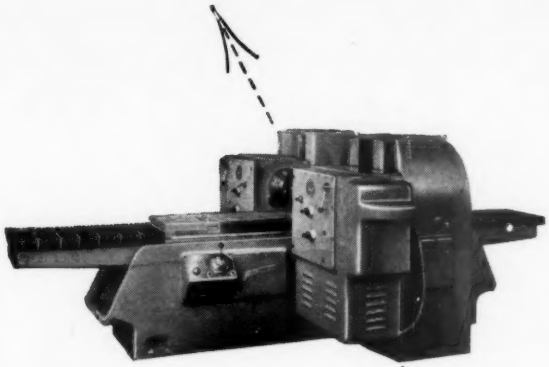

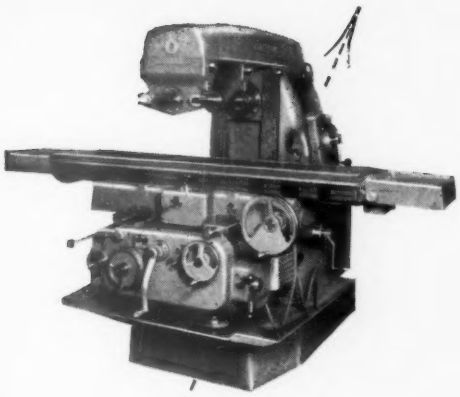

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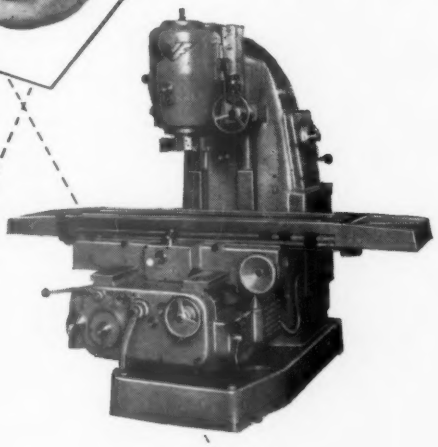

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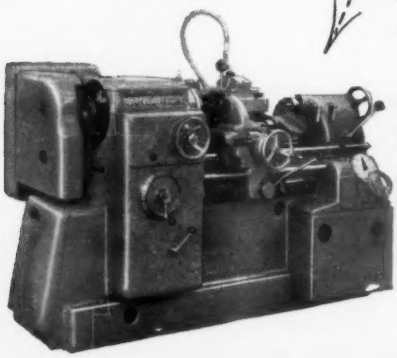

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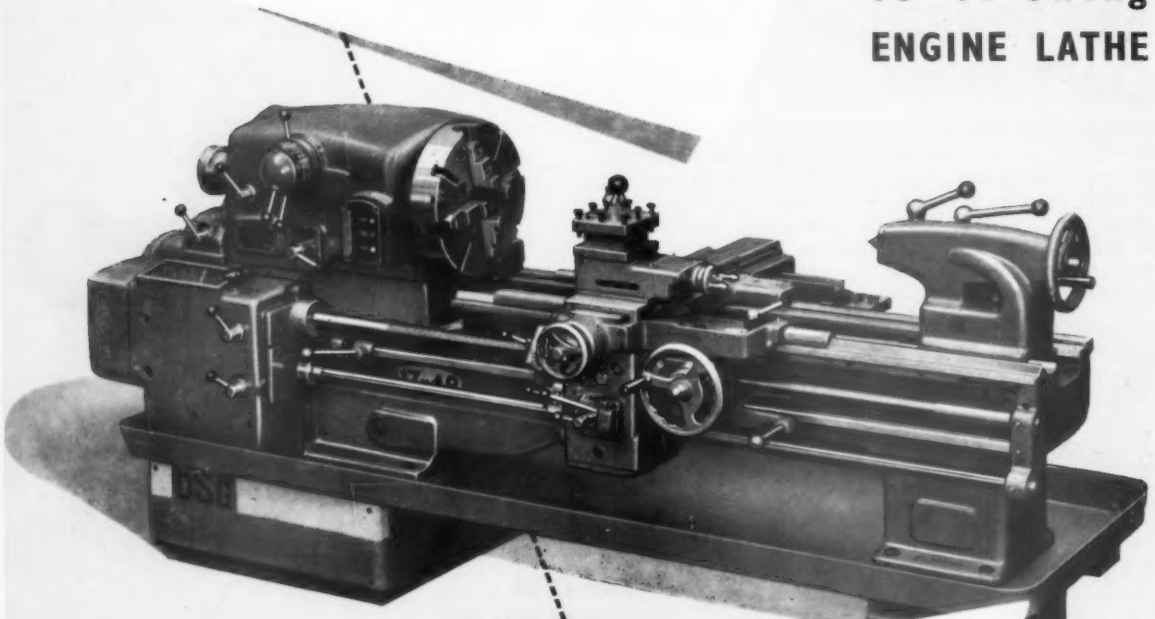

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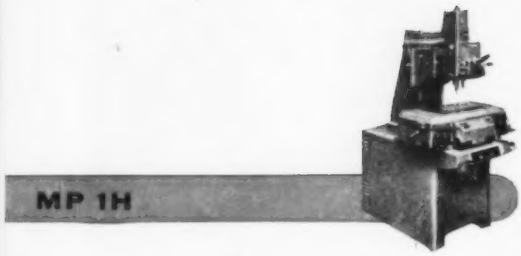

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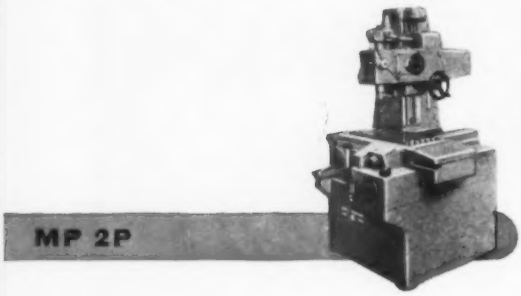
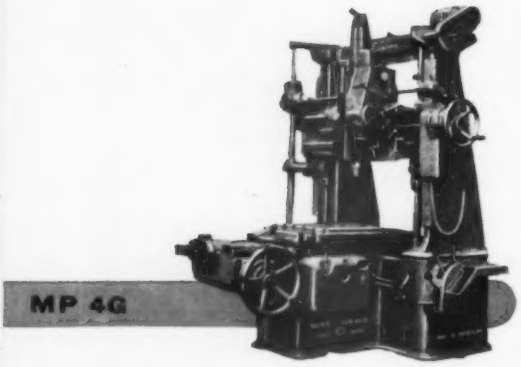


MP 2P

MP 3K



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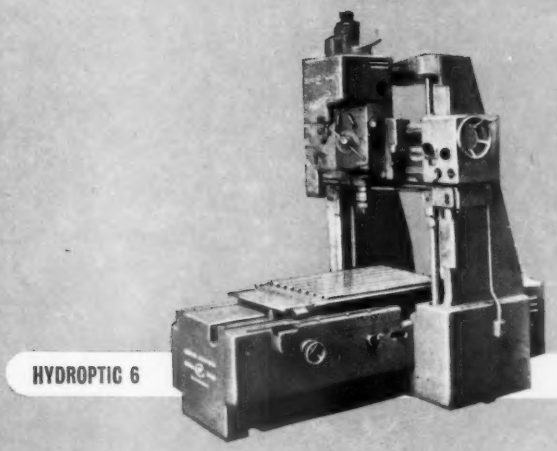
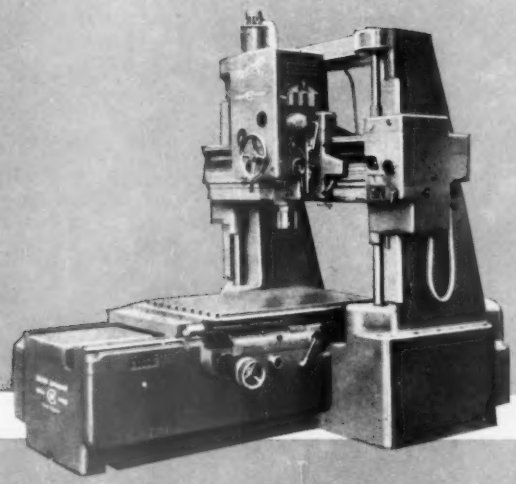


HYDROPTIC 6



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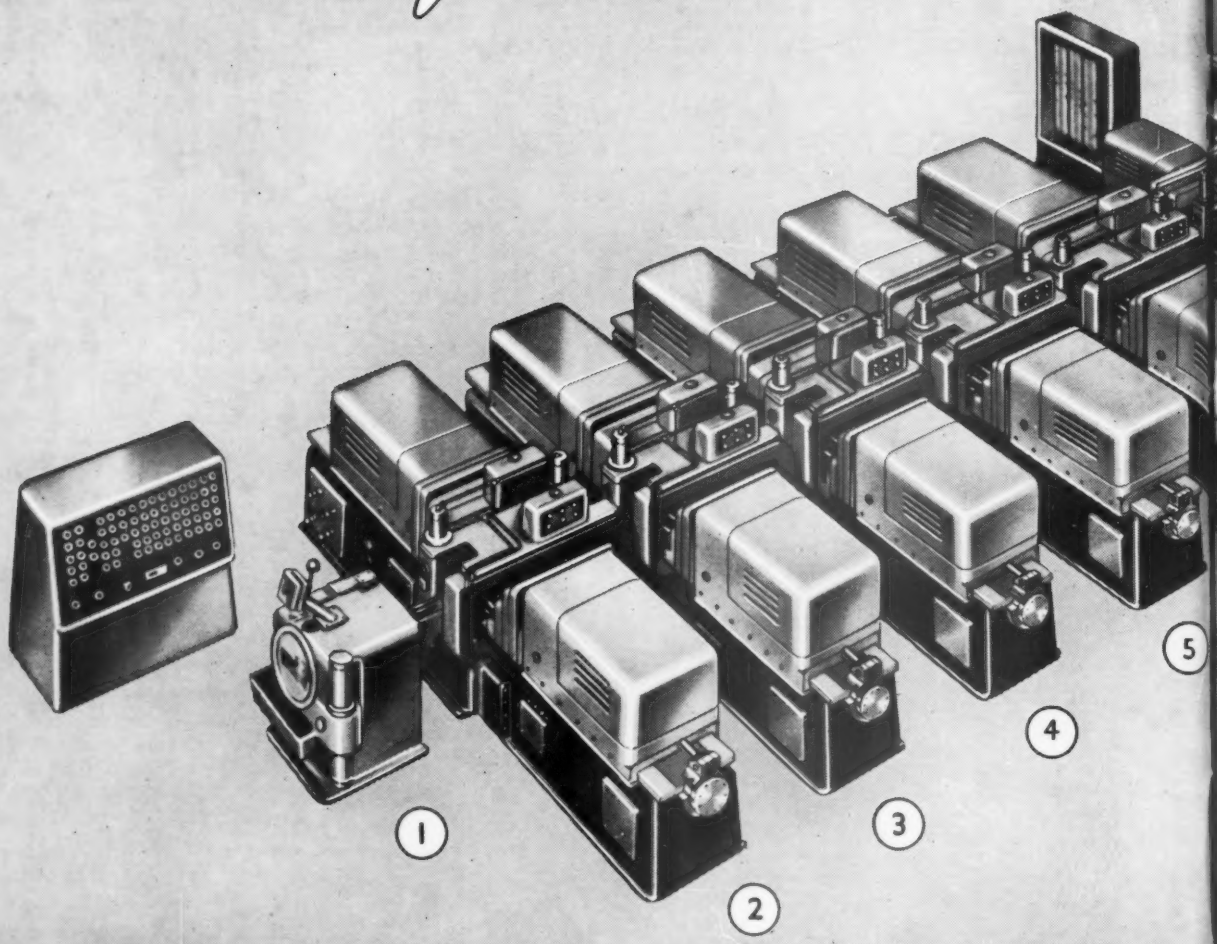
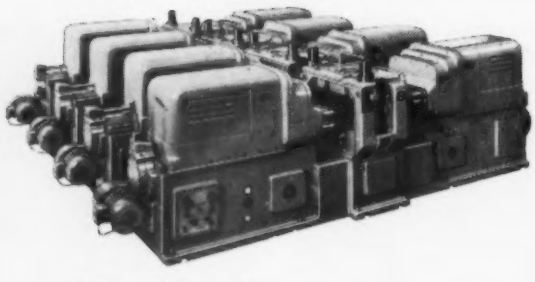
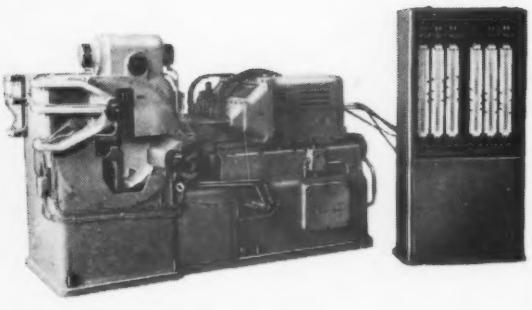


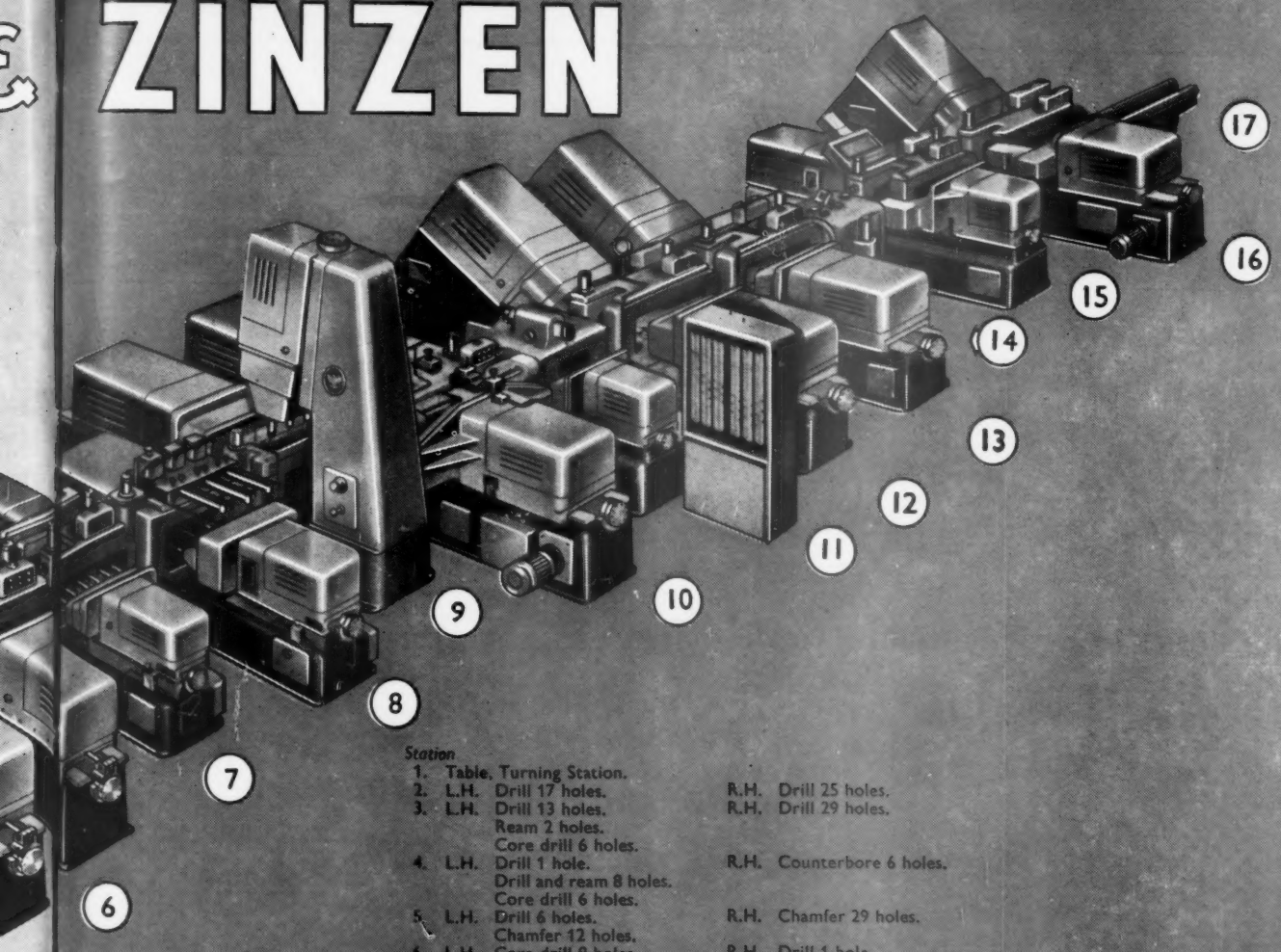


Stations 2, 3, 4 & 5.
Hydraulic units for drilling, reaming and counterboring.



Station 11.
Hydraulic turnover and gauging station.

ZINZEN



Station		
1.	Table. Turning Station.	
2.	L.H. Drill 17 holes.	R.H. Drill 25 holes.
3.	L.H. Drill 13 holes. Ream 2 holes. Core drill 6 holes.	R.H. Drill 29 holes.
4.	L.H. Drill 1 hole. Drill and ream 8 holes. Core drill 6 holes.	R.H. Counterbore 6 holes.
5.	L.H. Drill 6 holes. Chamfer 12 holes.	R.H. Chamfer 29 holes.
6.	L.H. Core drill 8 holes.	R.H. Drill 1 hole. Core drill 6 holes.
7.	L.H. Gauge 28 holes.	R.H. Gauge 48 holes.
8.	L.H. Press in 6 valve seats.	R.H. Tap 12 holes.
9.	L.H. Counterbore 12 holes.	*Vertical.* Drill and chamfer 2 holes.
10.	L.H. Ream 12 holes.	R.H. Core drill and ream 1 hole. Drill and chamfer 2 holes. Gauge 12 tapped holes.
11.	L.H. Turning Station.	R.H. Gauge 12 valve guides.
12.	L.H. Drill 6 tapping holes.	R.H. Drill 8 tapping holes. Counterbore 3 holes.
13.	L.H. Counterbore 6 plug seats.	R.H. Chamfer 11 holes.
14.	Hydraulic Turning Station.	
15.	L.H. Tap 2 holes. Gauge 6 holes.	R.H. Gauge 11 holes.
16.	L.H. Tap 6 plug holes.	R.H. Tap 10 holes.
17.	Unloading Station.	

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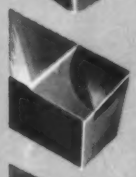

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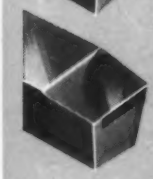

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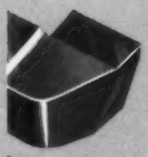

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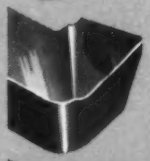

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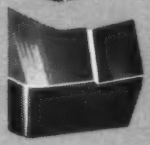
For light-duty turning and facing, boring and turning to square shoulders, etc.



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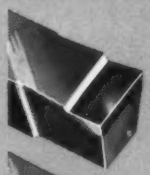

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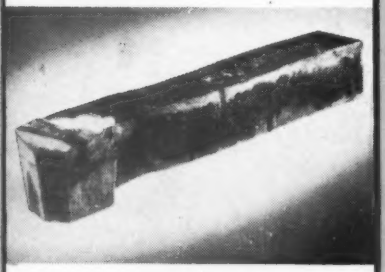

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The Institution of Production Engineers Journal
VOL. 35 NO. 1 JANUARY, 1956

DESIGNING FOR PRODUCTION — THE UTILISATION OF MATERIAL

by R. M. EVANS, M.I.Prod.E.,
Works Director, Imperial Typewriter Company, Ltd.:
Chairman, Materials Utilisation Sub-Committee.

THAT Great Britain is very largely dependent upon her manufacturing industries for the maintenance of her economic life cannot be denied. It is also evident that, no matter how efficient her primary production may be, it will be insufficient to provide for the population of these islands at subsistence level, let alone at the standard of living enjoyed at present by even the poorest.

This has been substantially true for the last hundred years, but the situation has become steadily more acute as the population has increased, and the effect of two major Wars, especially the last one, has been to drain away the reserves of overseas investments which acted as a cushion in balancing our budget and which gave us a measure of independence in our purchases in the world's markets. Furthermore, other nations have followed our lead and have become manufacturers, and have turned from being our customers to being competitors.

All this is obvious and should not need restating, but it would seem at times that not everyone fully realises how precarious is our situation; particularly is this so with regard to our use of raw materials.

Small Resources

This country's resources of indigenous raw material are small; many materials are not produced at all and, with very few exceptions, are far below the requirements of industry. We must, therefore, purchase a large proportion of our materials from overseas and the payment for them is a first charge on the profits from our overseas trade. In the case of home-produced materials, we must use power and labour to extract them and process them to the stage where they can be used. Power in this country is a scarce commodity; our main source is, of course, coal, which is being mined in insufficient quantities, water power is limited by our lack of large rivers and high mountains, and atomic power is not yet in a position to make a substantial contribution.

It is, therefore, essential that we make the utmost use of our raw materials whether they be imported or home-produced, firstly to see that we do not destroy, unnecessarily, the material during processing and, secondly, in order that we do not, indirectly, waste power and labour in our manufacturing processes.

Material may be destroyed in various ways. It may be vapourised or corroded away, or it may be lost because it is impossible to remake it into a re-useable form. Such losses are fairly obvious and, usually, some care is taken to reduce them to a minimum. What is less obvious is the waste that occurs through an excessive amount of work being put into the material to shape it to the required form; in the case of metals, shaping or turning from the solid can often consume a great deal of power and labour and produce a large volume of swarf which, although it can be remelted and used again, involves the loss of all the original work that was put into making the material, plus the loss of all the work in reducing the original material to swarf.

When it is realised that, in many cases, the swarf is as high as 70% of the original material, it will be appreciated that very substantial savings can be made if this condition can be avoided. Much can be done, and illustrations of examples that have been carried out in practice are shown in the Report of the Materials Utilisation Sub-Committee * of the Institution.

From the manufacturer's point of view, the returning of a large proportion of his material in the form of swarf is a bad proposition as, in most cases, he can only recover a small proportion of the cost of the material, and none of the cost of the machining that has taken place. From the point of view of the supply of raw material it is also bad, as there is always some loss of weight and much of the swarf is or may be contaminated and cannot be used for the highest grade material.

The foregoing is not in any way to decry the drive for scrap that is constantly urged by the steel industry. It is of the utmost importance that all unwanted material is returned for remaking, but it should be material the scrapping of which cannot be avoided. The returning of swarf is not in itself a virtue if the original material could have been used to better advantage. One is reminded of the old lady who, during the War, read of the need to riddle the ashes from her fire: as she had no ashes, she lit a fire to get some!

The economic situation in this country is so serious that our very existence depends on the improvement of our industrial efficiency. Somehow or other we have got to produce more goods at less cost or, whether we like it or not, we shall cease to be a great trading nation and we shall be unable to support our population. It is no use simply blaming the workpeople at the bench or machine and saying they must work harder; it may be true that they should, and an increase in effort is certainly wanted, but it is every bit as much a problem for management.

A Function of Management

The planning of the proportion of material to be used is one of the functions of management, and in laying out a job for production not only should the specification of the material be clearly stated, but also the degree of utilisation should be equally clearly shown. When that degree of utilisation appears to be poor, immediate enquiries should be made to see if it cannot be improved. There is always a strong tendency for designers and production planners to continue using well tried methods of production. This is all very well, but in many cases these should be examined from time to time to see whether the process is the best that can be used, as it is not uncommon to find that the method used is one that was adopted many years ago when the job first went into production and no further consideration has ever been given to it. The method may have been the one used in the prototype model and at that time too little thought may have been given to effective utilisation of material.

Senior management should be made aware of the extent to which, in fact, material is utilised, and should make it their business to ask questions about it.

We should also examine the design of our goods to see whether they contain more material than is necessary for their purpose. As was said in Mr. Dyson's article last month, such phrases as "massive construction" and "robust heavy design" are no longer a recommendation for most goods, and we should look to our products to see whether we are selling dead weight that could be better used for some other purpose.

Indirect Savings

It is not only amongst direct constructional materials that savings can be made but also with paints, varnishes, plating materials and other finishes. In the field of ancillary materials such as solvents, lubricants and various other chemicals that are used in processing, there is undoubtedly a considerable wastage that goes on all the time due to carelessness, inefficient apparatus and poor arrangements for the recovery of residues. Such wastage is more difficult to check as quantities cannot

* Available from the Institution, price 5/- per copy (post free).

be so easily related to production, but a careful check over a period of the usage of such materials usually reveals considerable waste.

The improvement of materials utilisation is a directly paying proposition and businesses that have had an all-out drive in this direction have almost always made very substantial savings in cash. Furthermore, they have often eased for themselves the difficulties of obtaining materials that are in short supply.

Substitution of Materials

A line of investigation that should not be overlooked is the substitution of materials. This is sometimes looked on with suspicion, due, perhaps, to the exigencies of war-time, when inferior materials often had to be accepted. Substitutes are not necessarily inferior and may, in many cases, be an improvement — for instance, moulded nylon small gears are found to be an improvement both in cost and quality on similar gears made by diecasting, and quite as good as machine cut gears.

Considerable improvements are constantly being made in techniques and processes, and it is essential that manufacturers should keep up-to-date with what is being done; all too often a process has been tried once and found unsatisfactory for the particular purpose for which it was tried, with the result that that process, or anything similar, has been condemned for all time. This may come about because the process was in its infancy at the time it was tried, or it may be that it was tried in the wrong way or for the wrong purpose; if such an attitude is allowed to persist, progress may well be stifled.

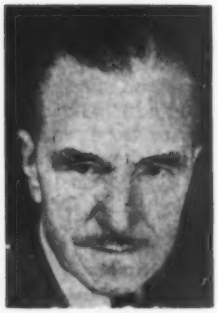
This matter of improving material utilisation is not a question of introduction of yet another specialist officer into the organisation. It should be the business of everybody who has to do with design or planning to be conscious of the need to use all material with the utmost economy. The greatest saving can usually be effected at the original design stage, when modifications can be carried out without difficulty, and it is at this stage that careful consideration should be given to the eventual method of production. All too often this aspect is overlooked and a design is passed through to the production department for tooling in the same state that it was tried out in the prototype model. Prototypes are usually made by hand methods and parts for them are produced by cutting away from the solid and, at this stage, there is little need to consider material economy, but before the design is finalised, great thought should be given as to how it can be produced in quantity and, if necessary, parts should be completely redesigned to facilitate production.

We should remember that in mass production even very small savings on an individual part amount to very large savings over a year and every saving that can be made without the sacrifice of quality is worth our while. Not infrequently a small saving per part will easily pay for the cost of special machinery to produce it by an improved method. It is essential that our costing system should produce statistics that show all the costs involved, both direct and indirect, so that we may properly compare the advantages of one method over another. Such costs as the storage and removal of swarf should not be overlooked, nor should the extra space required in our raw material stores be forgotten when we are looking at the savings to be made by improving the utilisation of material.

SOME TOOLING PROBLEMS IN JET ENGINE PRODUCTION

by R. E. ANDREWS, A.M.I.Prod.E.

Presented to the Melbourne Section of the Institution, 12th May, 1954.



Mr. Andrews

Mr. Andrews is Tool Room Superintendent of the Engine Division, Commonwealth Aircraft Corporation, Melbourne, and Lecturer in Jig and Tool Design at the Melbourne Technical College.

He also serves on the Committee of the Melbourne Section of the Institution.

IN order to appreciate more fully the problems associated with tooling for the manufacture of turbo-jet aircraft engines, it is necessary to consider not only the engine itself but the manner in which its production is to evolve.

Apart from the fact that jet engine manufacture involves some production processes fairly new to Australia, such as electrolytic polishing, investment casting and argon arc machine welding, also the machining of the notorious heat-resisting metals which all affect tooling, the main problems are brought about by (*a*) the requirement of extreme accuracy; (*b*) high finish; (*c*) the light and flimsy nature of some components of large diameter with high thermal expansion co-efficients; and (*d*) the innumerable blades of aerofoil profile requiring machining and location. (Fig. 1.)

Reverting to (*a*), one's first impression of a drawing for a major jet component is the formidable line of zeros after each decimal point indicating the tolerances (as little as .002″ for bolt hole centres and .0004″ for dowels up to 20″ centres) which brings to mind the paraphrase: "Never has so much depended on so little." The demands for such accuracy require the elimination of as much of the human element as possible in the measurement of large locating diameters, therefore most gauges are made to incorporate some indicating device. The other problems will be discussed under the heading of turning, milling and gauging.

Production

It has been the general practice when manufacturing under licence to commence assembling engines

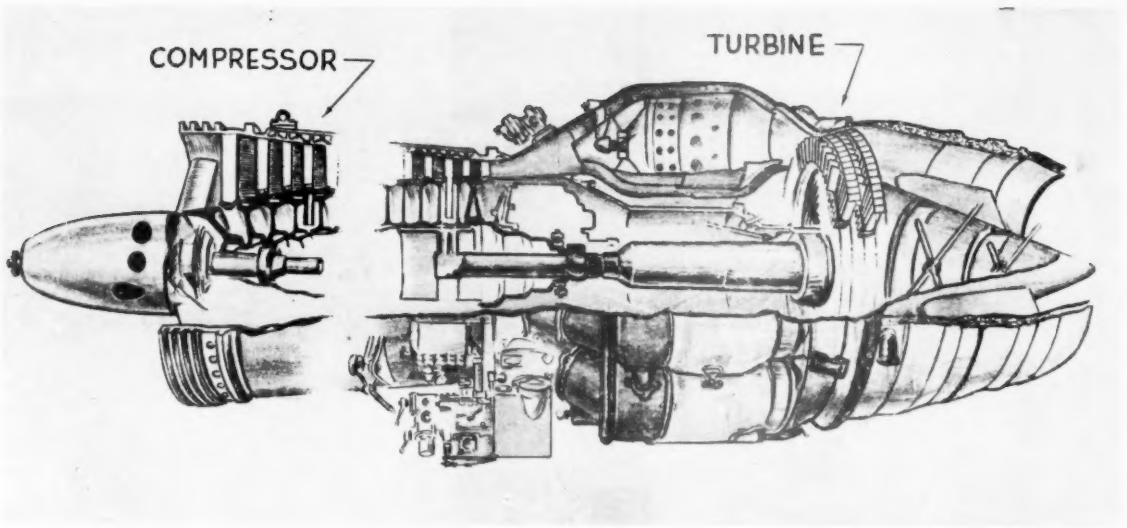


Fig. 1. Section through axial flow engine.

using a large proportion of imported major components and gradually tapering off, until practically the whole engine is manufactured. However, some of the major and more intricate parts involving many operations have to be tackled quite early and this is where the need for improvisation, such as will be shown later, becomes necessary.

Blades

Sections through the various compressor blades in axial flow engines could lead the more aesthetic to contemplate the graceful lines of the leaping salmon or darting porpoise, whose silhouettes they resemble, but one is brought to earth with the startling realisation of the stupendous task of gauging and location of such shapes. Fortunately for us, the production in a split second under the drop hammer of the form which Nature took millions of years to produce is the task of our compressor blade forging suppliers. However, the turbine blades have to be milled from Nimonic an l will be dealt with later, although the following average figures indicating the amount of work done on these units may be of interest: Forgings 1.46 lb., number of operations—61, finished weight 0.47 lb.

The compressor has 2,093 blades ranging from 2 to 8 inches long, and the turbine a total of 314, giving a grand total of 2,407 blades per engine.

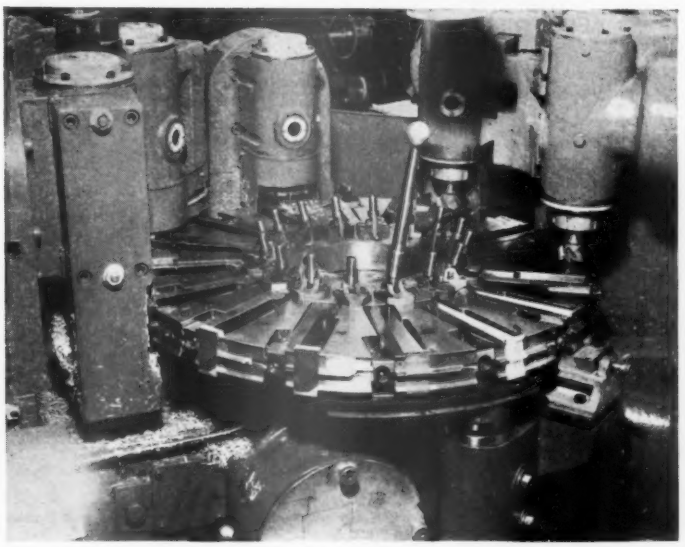


Fig. 2. Continuous milling fixture — stator blade platforms.

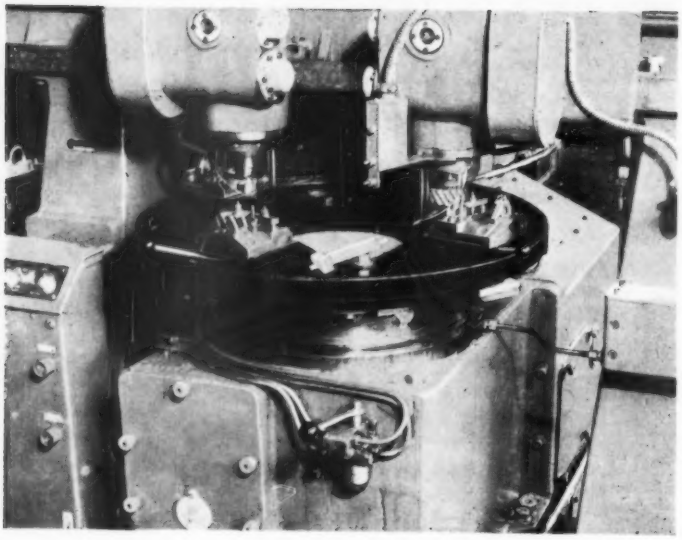
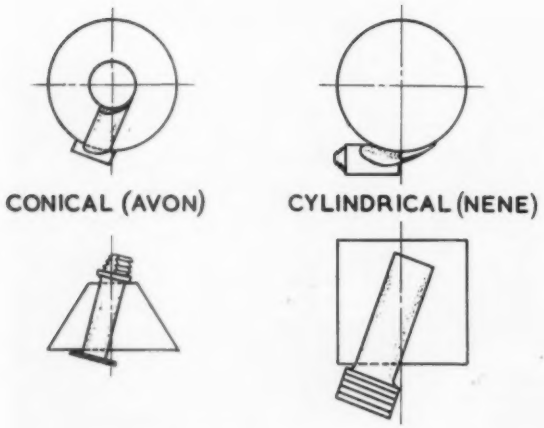


Fig. 3. Four-station milling fixture.

COMPRESSOR BLADES
AEROFOIL WITH RULING LINES.



TURBINE BLADES

The large number and variety of blades present a considerable problem both in machine tool and fixture requirement, and it is obvious that the general production picture as revealed to our team overseas cannot be slavishly copied, due to both limited finance and local defence requirements. Although some special purpose machines were necessary for the intricate profiling of turbine blades and casings, many compromises had to be made, involving changes in planning and tool design, but always keeping in mind the possibility of a sudden demand for full production. As an example, Fig. 2 is a continuous fixture for multi-milling compressor blade platforms, whilst Fig. 3 shows one only using four stations, semi-continuous. This table could accommodate a fixture with 12 stations at three times the tooling cost, but with the same cutter set-up.

Compressor Blades

These are forged in aluminium and bronze alloys. The blades are of aerofoil section and used as forged except for surface treatment and leading and trailing edge shaving; the early operations, therefore, require locating blocks for the inner curved surfaces in order to mill platform edges. Although of aerofoil section with co-ordinate dimensions from a chord line taken at established stations lengthwise, the twist is so designed as to give straight lines along the surface of the blade which we call ruling lines. A rough analogy would be a slightly-opened Japanese fan, Fig. 4, the tips of the ribs forming a curve which

Fig. 4. Comparative blade profiles.

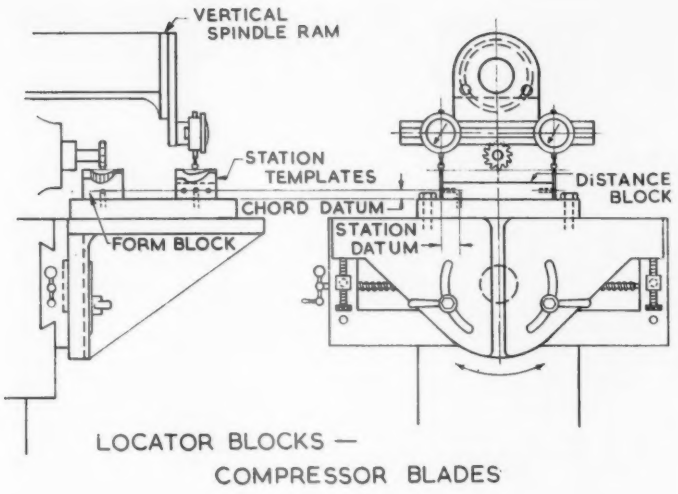


Fig. 5. Milling compressor blade locating blocks with ruling lines.

gradually flattens out to a straight line at the pivot point. Sections taken through the ribs at various stations throughout their length would produce different curves all connected by straight lines. A similar effect may be observed by twisting a pack of cards and noting the form made by the edges. This design feature greatly facilitates both the manufacture and inspection of dies and locating blocks, as it is only necessary to make templates for the two extreme stations (Fig. 5). These can be located at the correct distance apart and used to set the tiltable milling machine table to a pair of indicators as the table is traversed across the blade form for each cut. Indicator tips have the same radius as the cutter and are set to the same height. Fig. 6 shows a locating block after this operation ready for bedding to a sample blade, which is done with surprisingly little filing. Height and disposition of form are established by calculation to dowel dimensions of the templates, distance pieces and base for holding the blocks as shown in Fig. 5. All these dimensions, and practically every other dimension on these blades, is related to a point "P" usually in space and denoting the intersection of the x and y datum planes. The mere mention of this much maligned but very necessary spot is usually enough to cause the most extraordinary emotional reactions, ranging from tears to uninhibited vituperation, among tool and die people.

Nozzle Guide Vanes

These are investment cast from Crown Max, a heat-resisting alloy of .2C, .4Mn, 1.5Si, 11.5Ni, 2.5Cr, 3.0W, being used at the hot end of the engine, and have only to be ground on the platforms.

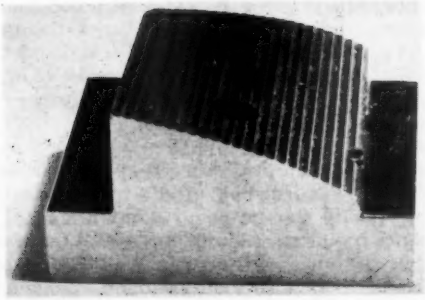


Fig. 6. Compressor blade locating block showing ruling lines.

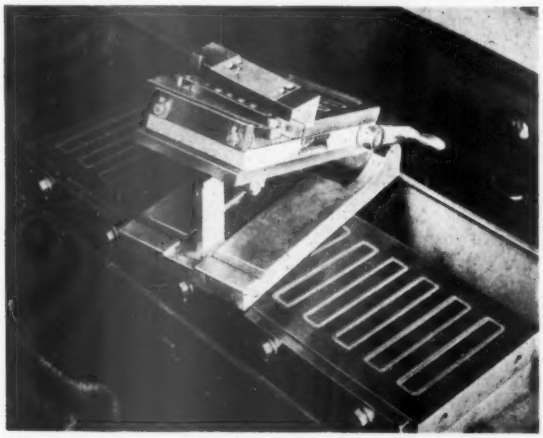


Fig. 7. Improvised magnetic sine plate using sine bar to obtain compound angle for turbine blade locator.

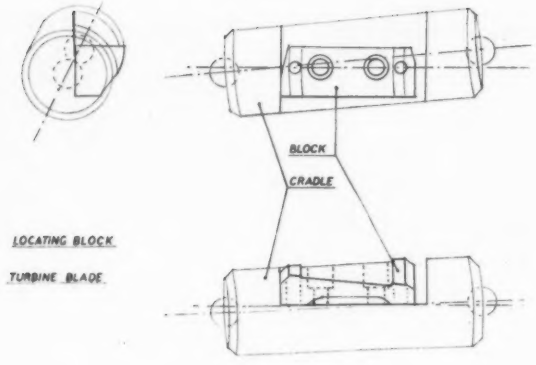


Fig. 8. Method of machining conical and cylindrical locators.

The location for these grinding operations requires a number of fixtures embodying compound angles and some confusion has existed regarding the interpretation of oblique projections as on the component print, but it was finally decided, after some deliberation and consultation with the Drawing Office, to show all compound angles in terms of tilt and twist[5] on the tool drawings. Although this may be "passing the buck" on to the design office, it has saved hours lost in the interminable discussions and cut and try methods entailing a hold-up of valuable machine tools, and the magnetic sine plate made up in the shop (Fig. 7), has well paid for itself.

Turbine Blades

The forgings for these have to be machined all over, and here again the designer has endeavoured to aid production in that the inside or concave surfaces have geometric shapes. The Nene blade takes its inside form from the surface of an oblique section through a cylinder, and the Avon an oblique section through the surface of a cone. Their locating form blocks can be turned and ground between centres from calculated dowel locations dimensioned from balls placed in accurately ground centres, enabling removal and replacement of blocks for each operation (Fig. 8). The Nene blades have their aerofoil convex side turned two at a time from a master cam, but others are milled on an 8-spindled profiling horizontal miller.

As the turbine blades are forged from Nimonic alloy (.94C, .5Mn, .5Si, 75.0Ni, 20.0Cr, 2.5Ti, 1.5Al) and constitute a considerable part of the machining difficulties encountered in jet production, it may be as well to give a brief description of the machining characteristics of this metal and some notes on the design of cutting tools.

Wolfe and Spear[1], of B.S.A. Research Laboratories, have published some valuable information on tool performance related to heat and creep resistant metals, but it appears, to quote from a survey prepared by Henry Wiggins, the makers[2], "that it is evident from information available that practice varies in detail."

Nimonic

Before discussing the design of tools something needs be said regarding the best condition in which to have this alloy for good machinability.

Although this material is far easier on cutting tools in its solution heat-treated state, it is difficult to obtain a good finish as the chip formation is not clean, with a tendency to plucking and tearing. It is therefore recommended by the makers that completely aged material be used where good finish is required.

The properties of these alloys at elevated temperatures are such that, at high surface speeds, the chip does not become plastic as in the general run of alloys; furthermore, any deformation is accompanied by an extraordinary tendency to work-harden; thus the tool designer is confronted with an almost impossible specification of (*a*) large top rake and clearance angles, and (*b*) great strength at the cutting edge. As any increase in (*a*) tends to decrease (*b*) it is necessary to reach some sort of compromise, usually by experiment, and it has been found that almost each job becomes a problem of its own and may need a specialist on the job at each new set-up and, generally speaking, the work of tool-sharpening must be taken from the operator and confined to a central crib with adequate facilities for grinding, binning and performance recording. Neglect of this has led to apparently conflicting reports and recommendations made for machining Nimonic and the reluctance of technical authors to "stick their necks out." However, it is thought that a few points taken from actual experience in our shop may be of interest without causing any highly technical controversy.

Turnings

1. Negative rake tipped tools appear to be ineffective and existing grades of carbides have been found too brittle to stand the small tool angles required. (Although G 18B stainless has been machined with 44A tips at 100 ft. per min.)
2. A maximum cutting speed of 30 ft. per min. for all machining operations except broaching (3-8 ft. per min.) and form broaches (12″-18″).

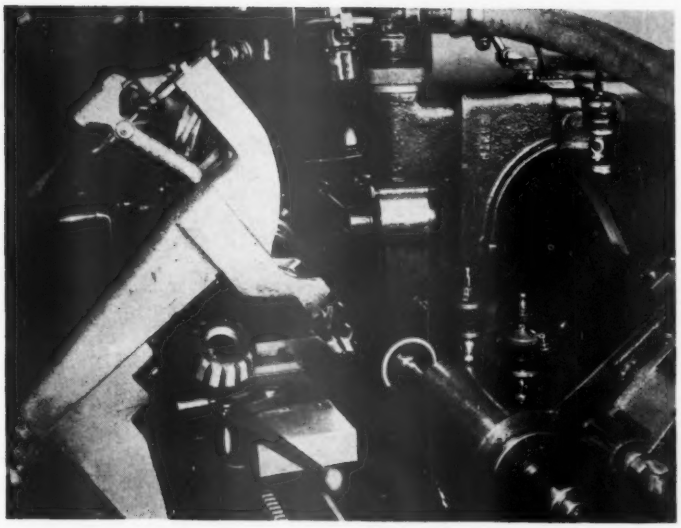


Fig. 9. Improvised small wheel head and tailstock for Jones & Lamson thread grinder for grinding form relieved fir tree root cutters.

3. The most useful type of tool steel has been one of 22W, 12CO, for the turning and drilling, but a high carbon, tungsten chrome vanadium steel has, according to Wolfe and Carr[3], given excellent results.
4. To reduce friction and heat caused by high cutting forces an extremely high finish must be imparted to cutting edges and even the most microscopic serrations removed. Sometimes even a .002″ bevel is quite effective. Some claims for improved cutting overseas are made for surface treatments such as Golden Arrow and Blue Arrow by Wolfe[4].
5. Tool, work and machine must be rigid as chatter is fatal. Drive must be smooth and powerful, as any deceleration may cause spots of work hardening.

Coolant

Extreme pressure oils are recommended and the supply must be copious and filtered, as any particles held in suspension are harder than the workpiece through work-hardening and can scratch and indent the work. This applies particularly to reaming and broaching where the coolant may be trapped in the tooth spaces. A good "wetting" additive is an advantage.

Milling

The price of free machining is "eternal vigilance" on the part of the operator when milling Nimonic, as tools can break down completely in a few revolutions when allowed to become dull, with disastrous results to both cutter and work. Sharp-cornered cutters can acquire a $\frac{1}{8}$th radius in a few seconds and work becomes too hard to re-machine.

High speed steel is used exclusively and to obtain a good grain structure cutters are much better made from forgings, as a considerable amount of bar stock is rejected for having a poorly spheroidised structure. Where possible, steep right-hand spiral flutes up to 45° are used for end mills for best results. Flutes must have ample chip space owing to the resistance of this metal to tight curling; the tightly curled chip area should be multiplied by at least a factor of 8. Primary clearance should be from 5° to 7°, although Wolfe and Spear recommend 5° to 8° with a .005″ to .010″ land at 2°. We have found that a land is produced after the first few cuts with 7° clearance and the tool continues to cut well like this. Rake angles should be as large as possible; about 5° is the general practice but anything greater should be used only with a spiral flute. Cutting speeds up to 30 ft. per min. are recommended, but experience has proved lower speeds to give better cutter life when used in conjunction with heavy feeds, never less than .002″ chip thickness per tooth, to avoid rubbing and consequent work hardening. Climb milling with the tooth starting its cut at full feed depth is ideal for this material. As an example of the sensitivity of Nimonic to any variation of cutting speed, on the boring operation inside the Nene turbine blade at 35 ft. per min., only nine parts per grind were completed whereas at 25 ft. we obtained 100 parts.

Form Relief

Ground form relieved cutters, such as those used on the fir tree blade root work well, having a cam rise giving 7° relief angle, more relief being difficult to produce by grinding even with a 3″ diameter wheel, owing to interference (Fig. 9). Modifications have been made to our Jones and Lamson thread grinder to use small wheels. This involved replacing the normal wheel head cover with a fabricated outrigger spindle housing using the normal 20″ wheel spindle as a countershaft. The standard internal wheel dressing device of simple rocking-lever type is used and a special back centre made up to clear the wheel spindle.

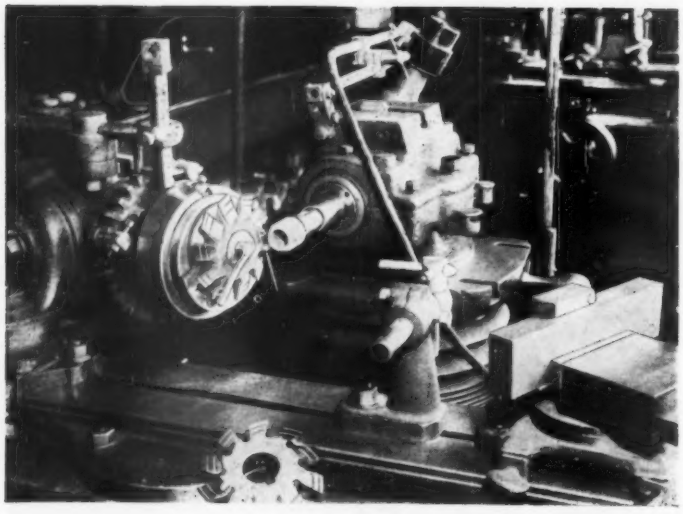


Fig. 10. Eccentric grinding turbine disc slotting cutters. Peripheral dresser, centre. Cone dresser, right. Stops attached to index plate.

The 5″ diameter ground form relieved cutters for slotting and chamfering the turbine discs prior to fir tree broaching (Fig. 10), are ground using the periphery of a $1\frac{1}{2}$″ diameter wheel to enable full relief back to the gash, a cone being dressed on the wheel to grind the chamfer at the same time and so obviate the need for blending two operations. As will be seen at the right of the picture, angular dressing is accomplished by a diamond held in a small angle block and sliding along a ground strip held in a vice set to correct angle. The relieving fixture is an old eccentric boring head from a Theil universal miller, which is set to approximately $\frac{1}{4}$″ offset, the tooth being ground when located with its centre about 90° from the direction of the eccentric throw. This position gives a very close approach to the Archimedian relief turned on the relieving lathe before hardening, (see comparative curves in Fig. 11). Distance d can be calculated at, say, 70° and 110° for trial values of b and approximate lead obtained if necessary without plotting, as under, where a is cutter radius, b is amount of eccentric and c is to be determined and subtracted from radius of eccentric path, a plus b = R. Then, for any angle A

$$\text{Sin B} = \frac{\text{b sin A}}{\text{a}} \quad \ldots \quad \ldots \quad (1)$$

$$\text{C} = 180 - (\text{A} + \text{B})$$

$$\text{c} = \frac{\text{a sin C}}{\text{sin A}} \quad \ldots \quad \ldots \quad (2)$$

$$\text{R} - \text{c} = \text{D}.$$

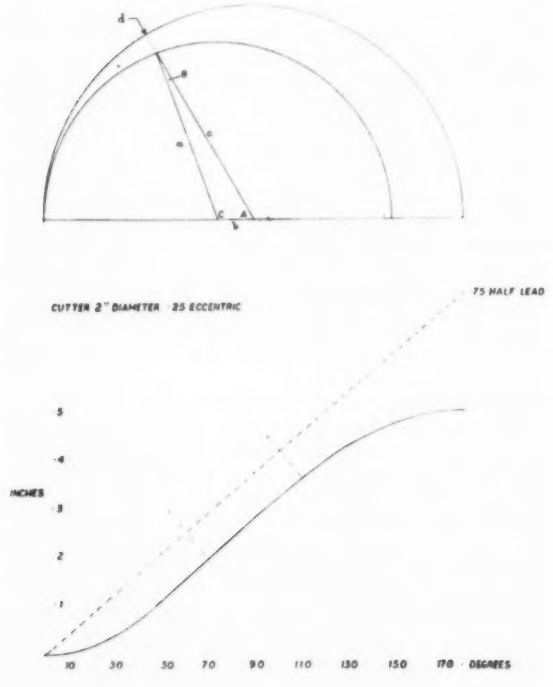


Fig. 11. Eccentric curve comparison.

Now find the difference in D between the selected angles, then the difference multiplied by 360, divided by the difference in angles, equals the lead of spiral which, divided by the number of teeth in the cutter gives the cam rise or, to express as a formula calling the selected angles E and F and number of teeth N then,

$$\text{Cam rise} = \frac{360\text{D}}{(\text{F-E})\text{N}}$$

Example shown:
a = 1″
b = .25

D at 70° = .193 (using (2)
D at 110° = .357
D = .165

$$\text{Cam rise} = \frac{.165 \times 360}{40 \times 8}$$

$$= \tfrac{3}{16} \text{ approx.}$$

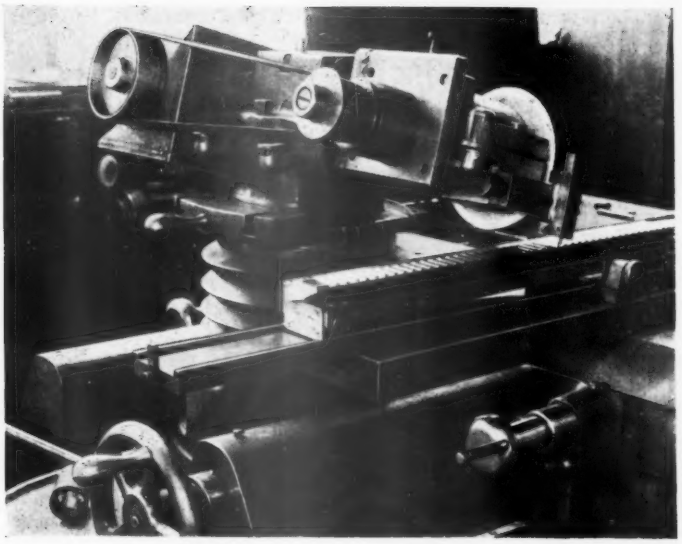


Fig. 12. Improvised broach sharpening on Cincinnati tool and cutter grinder.

Work is held on a hardened and ground spigot, indexed to spring loaded fingers and clamped. The whole fixture is then rotated, the movement being restricted to one tooth by stops placed in the index slots of the work head. Length bars at the table stops are used to locate the two diamond dressers in their correct position, thus saving much time in picking up the wheel positions. The amount dressed is governed by the stop adjustment screw. Some final adjustment was required to establish exact eccentric, and angular position and final setting noted for the future.

The problem of relieving the smaller spline cutters was overcome by cutting a bench block in half and milling "V" ways for ball tracks between top and bottom plates. To the top plate, free to roll in and away from the wheel, was welded a mild steel plate carrying the boss for the spindle bearing and studs for the change wheels borrowed from the Cincinnati miller. A hole was bored in the top plate to take a shaft, on which was mounted a cam purloined from the relieving lathe for which a recess was provided and the whole spring loaded against a hardened block in the base plate. A keyway was milled in the top plate to accommodate the standard machine centres supplied with the tool and cutter grinder on which the fixture was used.

Later, it was found that by reversing the direction of the spring loading, removing the cam and placing a micrometer stylus on the top plate profiles could be produced on peripheral ground cutters from a master form held on the wheel head platform.

Broaching

The 54 turbine blades in the Nene engine have a serrated root form of the fir tree shape, so familiar in turbo-jet engines, and are attached to their discs by sliding axially into serrated slots round the periphery. These slots contain three machined elements on which broach wear is unequal. It is necessary, therefore, for reasons of economy to separate the broaching into three stages, although performed in one operation. The first is the fir tree, next the radius at the bottom of slot which is extremely critical as to dimensions and finish in order to avoid stress concentrations, and finally the chamfering broach. All of these broaches presented problems and will be dealt with in the order mentioned.

As the fir tree broaches were all imported, it was considered that there was plenty of time to obtain or make a machine for sharpening them, but to our dismay it was found that the broaching of only two discs was sufficient to impair the finish produced and occasionally only one.

The usual practice in an emergency is to turn to the tool and cutter grinder for at least a temporary expedient, as there is practically no limit to the number of ways one can twist and tilt the various tables, attachments and wheelhead (Fig. 12). The wheel head was removed and replaced by a length of B.M.S. shafting to one end of which was spigoted a welded bracket to carry a quarter horsepower motor, and at the other, driven by a $1\frac{1}{4}$" cotton belt, a spare wheel head from a No. 2 Brown and Sharpe surface grinder. This brought the wheel sufficiently far out at the side to enable the top table, normally used for angular or taper setting, to pass underneath it when swivelled at right angles to its normal position. It will be noted that the whole motor and wheel assembly can be turned in its housing, thus providing the necessary tilt for rake and clearance angle on the wheel.

The broach (approximately 24" long) was mounted on an accurately ground channel section carriage provided with small shielded ball races rolling on the base plate, one set of races being on an eccentric spindle to provide for taper adjustment by raising or lowering one end. The carriage could be clamped whilst a tooth was being ground.

Tooth spacing being irregular, a common practice to avoid chatter, it was necessary to index at the tooth being ground and to provide means of retracting the finger after clamping. The broaches had 47 teeth rising in .0017″ increments, and eight finishing teeth, and owing to the small clearance angle, 1°30′, the apparent wear after use was as much as .040″ back from the cutting edge, the actual wear viewed on a projector being about .020″; therefore, to preserve the life of the broach, sharpening could not be confined to the front of the teeth, but was divided between front and top. Plunge grinding at 1½° was discarded as the wear of the wheel tended to spoil the cutting edge, so the whole broach was tipped up to 1½° in order to allow traverse across each tooth. To finish off, the increments were checked with a fine straight-edge over several teeth. The index finger was attached to the wheel head and lined up with the wheel by an adjusting screw.

The root broach was of unorthodox design, in that the top flat part of the roughing teeth were provided with a 2° clearance normal to a 5° shear angle, whilst the radii at the corners were to be relieved also at an angle to the side of the broach. With such specifications as these, it is not unusual to compromise and make a broach that still works, the tool design department being then presented with a *fait accompli* and a request for drawing change. This request was readily granted as the original design was imported, and not our own. The alteration led to the fabrication of a gadget for attachment to the Cincinnati cutter grinder head with a vertical slide, which allowed for dressing the full form on a small wheel, using the rocking bar principle with the diamond holder taken from the Jones & Lamson thread grinder internal attachment. The device was hinged so as to swing clear of the wheel when grinding and yet still be able to resume its former position. The vertical slide allowed diamond feed, and was operated from a knurled knob at the top. Full form could now be ground at 2° clearance parallel to the side of the broach, and the error due to the 5° shear angle was ignored as the finishing teeth had no shear. To speed up resharpening, the shear angle on later broaches has been deleted with no appreciable detriment to finish or tool life.

Chamfer broaches as imported gave trouble by scoring the work. This was caused by excessive chip loading at a spot on the tooth behind the chip breaker groove of the preceding tooth. These grooves were omitted in subsequent broaches, as it was thought that such a refinement was unnecessary with a cut only ¼″ wide.

Considerable warp and twist was encountered during the resharpening of the long broaches, but was overcome by constraining the broach movement in a holder similar to that used in the machine. This is one case of many where the so called "legal aspect" of inspection of the tool itself must be relaxed in favour of a functional check governed by the part tolerance. Another case was the form relieved fir tree milling cutter shown previously (Fig. 9), which, owing to the complicated relief mechanism employed in the thread grinder, had slight radial variation from step to step and from tooth to tooth for which they were rejected. In an emergency caused by delay in delivery of overseas cutters they were tried out on dummy parts and produced an even more accurate form than had previously been achieved. Apparently the errors had cancelled out in production. Their comparative behaviour was mentioned earlier.

Some interesting surface broaching experiments have been carried out with simple tooling fabricated in the production shop using an inserted tooth slab broach having a 30° shear, 10° normal rake, and 5° clearance variation in tooth height, increment being obtained with tapered backing plates or wedges placed under the complete broach assembly. This was used to augment production on the milling operations on the Nene blade root prior to machining the fir-tree form, therefore, times can be easily compared, being shown in Table 1. Cut was ½″ × 2″ long and the milling time was 7 min.

TABLE 1

Chip	*Depth*	*Feed per Min.*	*Cycle Time*
.002	.05	7′	45 sec.
.004	.10	3.5′	65 ,,
.008	.20	3.5′	65 ,,

The comparison between tool life in broaching and milling is even more enlightening:

TABLE 2

Tool Life-Broaching. (Milling 40 parts per grind.)

Chip	*Feed per Min.*	*No. per Grind*
.004	18″	2,700
.004	3.5′	2,000
.006	3.5′	2,000
.008	3.5′	1,200

It may be thought that the re-grinding time for the broach may be considerably longer than the milling cutter, but this is not so, as the inserted teeth are easily dismantled, placed in a fixture and all sharpened together on the surface grinder.

Drilling Nimonic

The design of twist drills calls for the same steep rake and large clearance angles demanded in lathe tools and milling cutters, also greater strength and hot hardness than standard drills. This necessitates steep spirals, short flutes and thick webs, and what is most important, they should be made from a really good quality steel. To indicate the position for a drilled hole by a heavy centre punch mark in Nimonic would be, to say the least, entirely misleading as to its eventual location, if any, as no ordinary drill will ever penetrate such an effectively work-hardened spot. This characteristic demands strict attention to the thinning down of the drill web to ensure the minimum of dead or non-rotating point, also to the provision of ample clearance to prevent any tendency to rub and work-harden. Any other precautions such as correct speeds and feeds come more under the heading of production and are usually the result of

careful experiment and close observation of results of which the grinding crib and tool design should be kept informed, but suffice it to say that drills must be kept cutting at all times at no more than 30 ft. per min. and never allowed to "dwell", or immediate work-hardening will ensue. Some success has been achieved with the "gun" type of drill where work-hardening is troublesome—the point being offset and operating more in the manner of a trepanning tool. It must be reiterated that the quality of steel from which the drill is made is of major importance. The most expensive drill does not cost as much as a scrapped component or the time lost before futile efforts to re-drill are abandoned.

Tapping

Taps should have extremely good finish to reduce friction and as much hook or rake as possible up to 15°, and should be highly polished to avoid resistance to clean chip curling. It should be remembered that chips are work-hardened and thus capable of damage to the threads produced, therefore radial relief must be kept to a minimum and it must be ensured that the back face of the land is at least radial and never with negative rake, which would tend to jam the cuttings between the outside diameter of the tap and the hole on reversal. Here again, considerable success is claimed in the United Kingdom for patented surface treatments on taps. Wolfe[4] has postulated an austenitic layer on ground surfaces which this treatment eliminated and which produces an anti-friction surface. Trichlorethylene is an excellent tapping lubricant for heat-resistant and stainless alloys.

Reaming

The compressor rotor blades are attached to their discs or wheels by means of pins fitted to holes of extreme accuracy and high finish. In the case of the stainless steel discs, draw reaming is specified, using tipped reamers with alternate teeth of opposite helix, the smallest of which is only about .200″ diam. and 7″ long necessitating the use of diamond wheels and extremely sensitive precision cutter grinders. Very high finish is imparted to the land, lead and rake. Other reamers of H.S.S. used on the aluminium alloy rotors at the "cold" end of the compressor are honed with very fine Aloxite and India stone cup wheels, the clearance being taken right to the cutting edge and completely removing any trace of radial land. It may be contended that such a reamer would soon lose size and, unless running very true, produce oversized and bell-mouthed holes. Contrary to expectations, this has not been the case since, when used in an accurately bushed jig, even on an old machine, holes of correct size and excellent finish have been produced without any undue reamer wear. It has long been fairly generally accepted that the maximum diameter of a straight fluted reamer with radial lands, or cylindrical lands as they are often called, is found some distance back from the cutting edge, owing to wheel compression when hitting the lands as the diameter is being ground. This effect is even more pronounced with tipped reamers and can be demonstrated by using a cast iron lap charged with fine diamond dust and running the reamer backwards. As much as .0002″ is often required to bring the lapped diameter right up to the cutting edge. With the large number of reamers required, such a practice would be uneconomical, hence the honing away of lands of the high speed steel reamers and the use of peripheral diamond wheels for the tipped type, which incidentally are given a short back taper of about 4° × $\frac{1}{16}$″ long at the back end of cutting edges to prevent scoring the hole.

Brazing of Reamer Tips

High speed steel is used for the body of the small reamers and, after hardening, the tips are soldered in with low temperature rod (630°C) whose melting point is below the secondary heat treatment temperature of the body. Thus the hardness of the pilots is retained, but with the larger reamers, cost demands the use of case-hardening steel for the body and shank; this raises the problem of brazing in tips and still keeping the remainder of the reamer hard. Our Toolroom at Lidcombe advised us that they had been successful in quenching reamers after the tips were brazed in. We had already broken one cardinal rule of the tip manufacturers in confining the tips on three sides and one end and got away with it, so why not commit the heinous offence of subjecting them to thermal shock? The bodies were carburised, slots milled and copper plated .010″, and tips plated the same amount as it was thought that this might not only assist brazing but act as a cushion. Tips were brazed in, using high temperature bronze rod (about 875°C) and the whole quenched from 760°C. So far we have not had a cracked tip!

Reaming is eliminated in the case of the holes for securing the blades in the aluminium rotor wheels which are step drilled, the drills having up to five steps with the finishing size tipped. Trouble has been experienced in modifying some makes of standard drills, most of which have considerable run-out, up to as much as .018″ eccentricity between neck and taper shank on some and $\frac{1}{4}$″ axial displacement at the cutting end of others; this is not confined to local products. The stepped drills are slotted at the flute helix angle to take the tips with a small grinding wheel similar in shape to a Woodruff cutter and having the same radius as the back of the tip.

Jigs and Fixtures

The principal problem met with, particularly in the turning fixtures, is the demand for almost perfect concentricity of the numerous casings and rings which are generally of a flimsy nature and are difficult to hold and locate without distortion, also the effect of thermal expansion upon large aluminium alloy components of about 2 ft. in diameter. To overcome this, the fixtures are made from alloys having the same co-efficient of expansion as the components, which are located by a circle of 12 or more hardened and ground pins which, having only line contact, allow for a much closer fit on the component spigots with less tendency to jamming and damage than if

such a neat fit were attempted with a solid recess in a soft alloy fixture. It may be suggested that this line contact may exhibit a tendency to rapid wear but, so far, there has been no evidence of this, and in any case it is no trouble to turn the pins to new positions almost indefinitely. Care has to be taken with the fitting of these pins, particularly when used for face location, as any excessive tightness in their holes stresses the base plate and causes a wind or "swash", and flatness in this type of fixture is of the utmost importance, usually having to be within .0005″.

Gauging

With light components of large diameter the problem of effective gauging arises, especially with aluminium. Some rings are so flexible as to preclude the possibility of using flat plug gauges, owing to the probability of distortion, so the old-fashioned pin gauge has been brought into use. Extremely accurate measuring can be achieved without any pressure on the component bore by specifying so much "travel" at the top of the hole when the pin is resting on the bottom; thus, using Rolt's approximation for clearance $\frac{h^2}{8L}$ where h = travel and L = pin length, for a 2 ft. diameter hole and one end of the pin rocking as much as half an inch, the clearance between the pin length and hole diameter is only .0025″.

These pin gauges are usually made of the same material as that which they are to gauge, but with hardened steel spherical points and encased in a wooden handling block. Their method of finishing to size requires considerable care and is the result of some interesting experiments. With a length of up to 3 ft. and .0002″ tolerance, they had to be allowed to stabilise in the gauge room along with the made up length gauges for at least 2½ hours before checking, so naturally, with literally hundreds to make and replace, some quicker method had to be devised. The first step was to segregate gauges into batches falling within a 1″ range, then an aluminium bar was machined to take the 1/10,000th micrometer and fiducial indicator from a standard N.P.L. type thread diameter measuring machine which was set to standard gauges. The smallest of each of about eight batches was then roughly sized and sent to the gauge room for check after remaining there all night. Using these as standards and with the micrometer bed of the same material as the gauges, good results were anticipated, but failed to materialise on days of rapid temperature variation. This we attributed to, and later proved to be caused by, the difference in mass of the micrometer bed and gauge body, with a consequent time lag in temperature change. Quenching of the master and gauge seemed to be the only solution, so a 3 ft. length of 3″ pipe was welded to a base plate and placed vertically beside the grinding machine. Dilute cutting compound was used to quench work and master for 2-3 mins. and both were compared immediately, being handled as little as possible, using a cloth between hand and gauge; care was also taken to dry thoroughly, as it has been found that rapid evaporation on a hot day may cause sudden cooling if under a window in a draught.

An example of the degree of certainty using this method was demonstrated on another type of gauge. An 8″ aluminium flat plug with steel ends, was cylindrically ground. This job was required urgently during a hot spell when the temperature was 92°F, and having been ground was quenched in the machine's coolant tank at 78°F along with the standard slip gauges, the difference in expansion for 10° above standard temperature, .00067″ being allowed for; it was then measured under a tenths comparator and was eventually found by the gauge room to be within .00005″ of nominal size.

The behaviour of these length gauges during temperature changes is such as to indicate the influence of mass on the rate of change in length. In order to obtain some method of roughly estimating what could be expected, tests have been carried out which appear to indicate a relationship between the volume to surface area ratio and time taken to reach stability. To mention one case, two gauges were compared, one being 3″ diam. and 4″ long, and the other 1″ diam. and 4″ long, their volume to surface area ratio being 1.8 and 4.5 respectively. The thinner gauge had two and a half times the ratio of the other and under test at a room temperature of 84° after being quenched at 74° the 3″ diam. gauge took two and a half times as long to reach room temperature size. Another interesting feature is the change in the rate of growth which appears roughly exponential in form when plotted. Assuming a long aluminium pin gauge has contracted .0008″ on being quenched, to reach its original size at room temperature, it will increase .0004″ in the first hour, .0002″ in the second, .0001″ in the third and so on. This works both ways, so that a gauge sent from a warm shop into the gauge room for checking needs to rest with the standard set-up quite a long time for extreme accuracy. Any time and expense involved in these experiments has paid handsome dividends in the renewed self-confidence of the tool grinders on the type of work, as there is nothing more unnerving to a good toolmaker than to find errors occurring in his work for which he can find no explanation.

The method of producing accurate spherical points rapidly on pin gauges may be of interest as it is simple and effective. Gauges were held in a spring collet which was also used to accommodate the wheel dressing device, set to the prescribed radius and operated manually by slowly swinging round the pivot pin which could be stationed in one of several holes for different radii. By this method the dead spot in the centre of the rotating pin gauge is taken care of by the grinding wheel. Final polish is imparted to the point by inserting smooth emery cloth between the dressed radius of the wheel and revolving gauge whilst rocking the wheel slightly with a cloth held against it. A handy tip for use when small amounts have to be removed for correction is to have the gauging surface plated to provide means of " coming down " to size.

Banana Gauges

These are for measuring the "throat area" between the nozzle guide vanes, which has to be evenly disposed around the assembly for best performance.

The gap between the vanes at the tip, centre and root has to be accurately measured and the vanes so disposed as to give the same area in each of the four quadrants of the assembly. Gauges are used in conjunction with a fixture which locates them at the correct stations. The Nene gauges have a concave profile in the form of an arc and an outside shape which is a constant rise or Archimedian curve, giving .001″ rise for every degree round the arc as indicated by radial graduations. Early attempts to make these gauges from ground carbon steel stock were a failure owing to distortion; then non-shrink steel was used which was still not sufficiently accurate after hardening. The method now used is to rough mill to the approximate radius with the gauge held on the face-plate by extension pieces and located on dowels enabling both sides to be worked on at the one setting. The dividing head is geared to .360″ lead for milling the outside. After heat treatment the same method is used but a Dumore toolpost grinder is substituted for the end mill. Graduations are milled sufficiently deep to allow for surface grinding, using a 30° double angle cutter. Rough checking for correct nominal size is carried out with a knife-edged vernier and final measurement by an indicating device, employing knife edge points preset to slips. A later type of gauge, just to tax our patience further, is a double-ender having opposite curves, one end from nominal plus and the other from nominal minus with .002″ rise every $1\frac{1}{2}°$.

The gauging of turbine blade thickness (Fig. 13) at stations throughout its length at leading edge, trailing edge and centre position is carried out by a multi-pin gauge, measurement being taken over the end of pins by micrometer, the contact with blade being made with small spherical points. Holes for these pins are jig-bored at the various angles normal to the blade profile at the spot being measured, their centre line location being established from the fir tree holding block on the base to component drawing dimensions.

Measuring wires for the fir tree serrations and small fuel jet drills and gauges being so hard to procure, it was decided to try making them ourselves. After futile attempts at obtaining consistent results between centres, it appeared that centreless grinding was the only way out and as the production shop machines were too large another raid was made on the spare casting rack and scrap heap and the long suffering tool and cutter grinder was again recruited in a new guise. (Fig. 14.)

Considerable experiment was necessary with the work blade angles and height, and it was found that with the small sizes the range for each blade was quite limited. Whereas scrap on the .060″ wires between centres had been about 75%, it is now practically nil with accuracy within .0001″, using 35° blade angle and work .030″ above wheel centres. The grinding wheel is a 38.60 KBE., $5 \times 2 \times 1\frac{1}{4}$ and the regulating wheel, trepanned from a worn out production discard, was $3\frac{1}{8}$″ diam. and 2″ wide working at 42 r.p.m. The last work turned out with this set-up was a batch of 1 mm wires to be within .00005″ and, out of 16, nine were within .00002″ and the rest within tolerance.

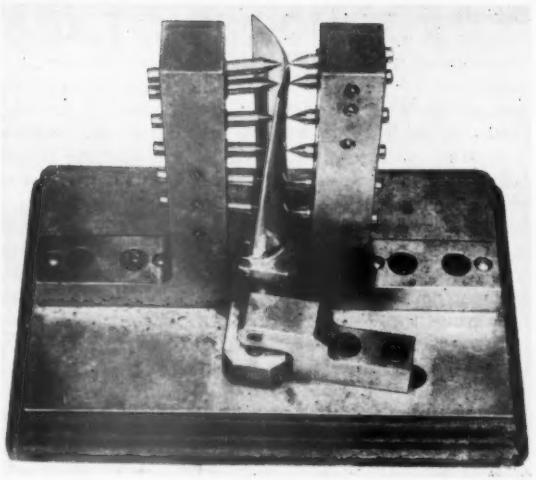


Fig. 13. Checking fixture for Nene turbine blade thickness. Note all pins have axes normal to blade profile.

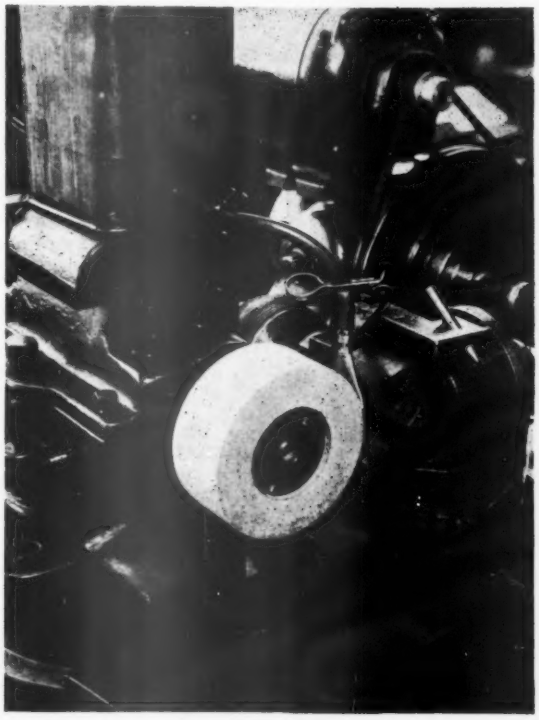


Fig. 14. Centreless grinding .050″ diameter fir tree gauging wires within .0001″. Diamond shown swung out of position dresses white wheel, which then trues control wheel. Workhead and motor are Cincinnati equipment. The rest is 'junk'.

Conclusion

In conclusion, it is hoped that some of the simple devices that have been illustrated as used on standard machines to perform tasks usually carried out by special equipment, may be of use to small shops who could be of great assistance to the aircraft and defence industries in time of emergency, but who are somewhat over-awed by the specifications and fine tolerances prescribed.

It has been said that the aero-engine industry is over-tooled. Such a remark may be inspired more by superficial impressions than by careful analysis. It must be appreciated that, whilst aero-engines are becoming more and more complicated and consequently require greater skill in their manufacture, the number of skilled tradesman has, owing to reduced margins, become less and less. Therefore, rather than risk the scrapping of components (which in some cases cost several hundred pounds even in the early operations) through lack of skill, every possibility of error must be eliminated by almost foolproof tooling. In spite of all precautions that are taken with even simple jobs to combat stupidity, the shop supervisors are constantly making up gadgets, not so much to aid or increase production, as to prevent spoilt work. While good machinists are driving baker's carts and serving behind bars, we must continue to rely on the few whose nature is more creative than acquisitive, to make production foolproof.

This introduces another subject for consideration, that of "unofficial" tooling made in the production shop. There is undoubtedly a place in the modern shop for this sort of thing, but it must be properly supervised, co-ordinated and recorded with the tool design and production departments either as a change or an addition. Consider the surface broach; this machine is constantly being tried and used to experiment on erstwhile milling operations, tooling being fabricated and tried on the spot with no experimental tool design cost until the successful fixture is recorded either for duplication or replacement. As another example, milling cutters have sometimes and on some materials had their output per grind increased 100% by changing the primary clearance angle from that specified to as much as 6° for a trial, when sent to the re-sharpening crib. When worn-out, new ones are made in the toolroom to the original prints, with the resultant reduction in output, and the impression that the toolroom can't grind cutters. Cause—no co-ordination—change was not recorded on the tool drawing issued with the new order.

In the old days, there was a tendency to regard the Tool Department as highly esoteric and any attempt to alter, improve or replace tools regarded at its best highly unethical, and at its worst a *casus belli* or walking ticket. Now there is more tolerance and tool design appears to have universally accepted the fact that much can be learned from the man on the job; hence the tendency to decentralise tooling in some large modern shops following the trend towards specialisation.

Acknowledgments

Much of this information has been obtained from supervisors on the floor of the production shop, some of whom are included below:

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Mr. J. Turk, Foreman, Blade Section, for Broaching Statistics.

Mr. F. Bloomer, Toolroom Grinding Foreman. Notes on gauge metrology.

Mr. M. Wright, Foreman in charge of Tip Grinding Crib and Experimental tipped tooling.

Mr. J. McGlusky, Photography and film strip.

Mr. L. Heath, Rolls-Royce Toolroom.

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ELECTRONICS AS AN AID TO PRODUCTIVITY

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Presented to the Luton Section of the Institution, 22nd February, 1955.

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After serving his apprenticeship with the B.T.H. Company at Rugby, he joined the staff in 1942. He has been engaged on the development of electronic remote position control systems for aircraft and naval armament, radar aerials and the like, and latterly has been concerned with machine tool control applications.

Mr. Stokes

Mr. Milne graduated B.Sc.(Eng.), Electrical Engineering, at the University of Aberdeen in 1952. He served a graduate apprenticeship with the British Thomson-Houston Company for 18 months, and joined the staff of Electronic Engineers, B.T.H., Rugby, in 1953. He has been concerned primarily with the development of the automatic positioning of machine tools.

THE production engineer, in his search to improve manufacturing methods, is making increasing use of a wide variety of electronic devices. In some instances, electronics may offer the most practical solution, but there are many applications in machine tool control where a choice has to be made between hydraulic and electronic systems giving comparable results.

The prime object of this Paper is to summarise some of the principal electronic techniques now available to the production engineer, and to present some basic problems for which an electronic solution is likely to prove practical and advantageous.

Electronic Control

General

Processing by electronics is now quite familiar and there are standardised equipments such as high frequency induction and dielectric heaters. The control of many industrial processes, either in part or whole, is now carried out with the aid of electronics, and quite often the equipments comprise timers, photo-electric counters, warning devices and ignitron contactors, all of which are now well known.

However, there is a wide field of application in process control and machine tool control for the special electronic controller, designed to deal with a

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particular problem, generally in association with existing mechanical equipment, and which has so far received little attention.

It is as well to enquire into the reasons for using electronic controls and to this end some basic properties will be considered, with special reference to the electronic controller.

Basic Features of Electronic Control

Electronic equipment will often give improved results compared with older methods in applications where a high order of precision of control is required. This is not due to any inherent precision in the electronic circuits as such, but is primarily due to the very small power required to control the circuit operation. For example, the controlling power for a typical amplifier is equivalent in mechanical terms to the power required to raise a domestic pin through a height of one foot in one hour.

It will be appreciated that to control a quantity to a given accuracy, it must be possible to measure it to within that accuracy. The high sensitivity and low power input which are characteristics of electronic controllers permit the use of precise measuring equipment which would be unable to withstand significant electrical or mechanical loading without impairing the accuracy of the measurement.

For example, consider a simple motor speed control. The speed of the motor is measured by means of a tachometer generator coupled to it, and the desired speed is represented by a D.C. voltage which is compared with the tachometer voltage in an electrical circuit. Any disparity between the two voltages causes the electronic control to speed up or slow down the motor until the two voltages are equal. It is important that only a very small current should be drawn from the tachometer generator, otherwise its voltage would not truly represent the speed of the motor. The speed of response of the motor can be made so quick and sensitive that it is far in excess of the control likely to be achieved by a human operator. This form of control is also capable of giving a wide stepless speed range.

Automatic equipment can frequently be employed to advantage in relieving human operators of the strain and fatigue often associated with repetitive operations, particularly when the attainment of a satisfactory result requires great care and attention. For example, photo-electric control can be used in conjunction with a pointer type of indicating micrometer to stop the feed of a grinding machine when the workpiece is within tolerance limits. The pointer of the indicating micrometer interrupts a beam of light at the appropriate reading and this operates a photo-electric relay which initiates the withdrawal of the grinding wheel. A number of human faculties can be reproduced by electronic means in a more consistent and untiring form than any human operator can provide. Also the speed of operation can often be increased by a substantial factor.

A further field for electronic control arises when a process or operation is to be controlled in accordance with a number of different variable factors. For example, when reeling wire, strip or sheet material, it is often required to maintain constant tension in the material as the reel fills up. Hence the torque applied at the reel must build up in proportion to the effective radius. It is not always easy to measure the radius directly, but it can be obtained from the ratio of the speed of the material to the speed of the motor. The speeds of the motor and material are measured by tachometer generators and these signals are fed to the electronic panel. The circuit computes the radius and regulates the motor armature current accordingly.

Providing that the various factors can be expressed as electrical signals, and only rarely is this not possible, electronic circuits can be designed to accept these signals and convert them to a controlling signal which corresponds with any reasonably straightforward mathematical combination of the input signals.

The motor speed controller and the reel drive just described make use of a closed sequence, as indeed do all accurate automatic controllers. The sequence of operation is closed since the error which is the difference between the desired value and the measured value of the controlled quantity, causes the controller to operate in a manner that reduces the error. Closed sequence controllers are liable to hunt, but modern theory reveals how they can be rendered completely stable; this type of instability can readily be eliminated without causing any appreciable increase in the total size and weight of the equipment.

"Priority" circuits, in which different signals take charge under specified conditions, are simply arranged. A very common example is the necessity of limiting the armature current passed into a D.C. motor.

Summary of Basic Advantages

It is evident that the electronic controller has several very desirable features which give it the following advantages over other systems:

(i) quick and sensitive response;
(ii) reduction of human fatigue;
(iii) greater consistency arising from the elimination of human errors;
(iv) versatility of application;
(v) ease of matching to existing equipment.

The very valuable facility of easy modification on site to meet conditions differing from those expected has been noted, and furthermore, this is generally an inexpensive matter as compared with other systems. However, it is a regrettable lesson of experience that such modifications are often made in attempting some degree of compensation for deficiencies in the machine or process to which the electronic device is applied.

Applications of Electronics to Production Processes

High Frequency Heating

The two general types of high frequency heating equipment are induction heaters and dielectric heaters. In the induction heater, the high frequency current flows in a coil and induces heating currents

in a metallic workpiece by transformer action. The dielectric heater applies a high frequency voltage to two plate electrodes between which is placed a non-conducting workpiece. In this case the workpiece forms the dielectric of a capacitor, and is heated by the dielectric losses set up in it.

Induction Heating

Induction heating techniques are extensively used in production lines for surface hardening of metals. Their great virtue, from a production viewpoint, is the fact that the hardening operations can be carried out at any point in the production line. There is no necessity to transport items to a hardening shop and back again. The procedure is quick, free from dirt or fumes, and has small heat losses, so that there is no undue rise in the temperature of quite small working areas.

The hardening process can be accurately controlled and does not depend on the skill of the operator. In many cases, the heated surface layer of metal can be brought up to temperature so quickly that the temperature of the layer beneath is scarcely affected. When the power is removed, the cool layers beneath the surface chill the heated layer very quickly, and a self-quench action occurs. The depth of the heated layer is largely determined by the frequency of the high frequency supply given by the generator.

When the depth of hardening required is too great for the self-quench action, normal quenching with oil or water may be used. High frequency heating shows an advantage here in that the depth of the heated layer need be no greater than that which the job demands. Hence the heat content of the specimen is much smaller than with through heating, and the heat can be removed more quickly without surface cracking. This often permits the use of a water quench, giving a quicker and cleaner job than can be obtained with an oil quench.

A 10kW heater is shown in Fig. 1. Alternators are sometimes used to generate high frequency supplies for heating purposes. Generally these are used on large through-heating applications, where considerable power, say 100kW or more, is required. Alternators cannot produce sufficiently high frequencies for heating very thin surface layers, nor are they as versatile as the electronic high frequency generator.

Dielectric Heating

Dielectric heating is not used so extensively as induction heating, as it is not applicable to metal working industries.

One important application is the pre-heating of moulding materials. Thermosetting moulding materials must be heated under pressure in a mould, and maintained at a specified temperature for some minutes to complete the "curing" process. Much time in the press can be saved if the moulding material is heated before it is placed in the mould. If, however, the block of material is heated in an oven, in the time taken for the centre of the block to reach a sufficient temperature, the outer layers have advanced too far in the "curing" process to give a satisfactory result when placed in the mould. Dielectric heaters offer an elegant solution, as the heat is generated uniformly throughout the material, and the temperature can be brought up very quickly.

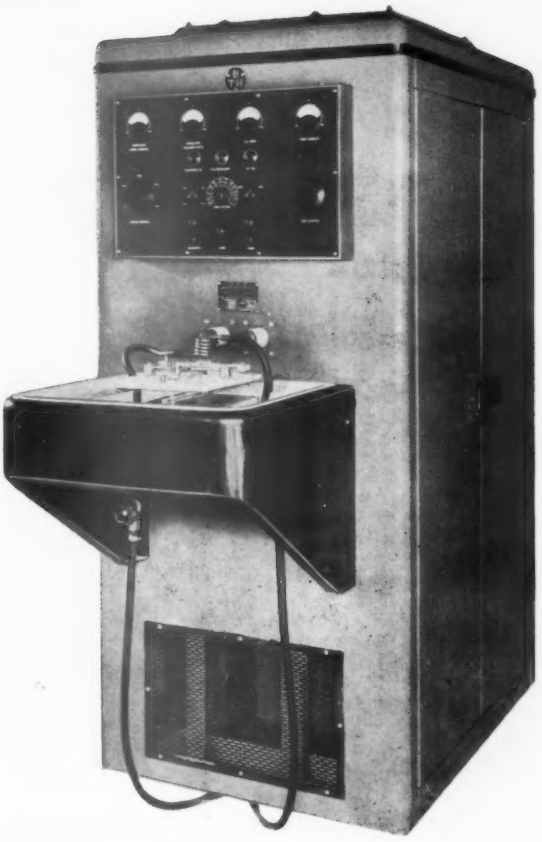

Fig. 1. 10 kW induction heater.

A dielectric heater of 1 kW capacity is illustrated in Fig. 2. The heater is versatile, and can deal with a wide variety of types and weight of moulding materials. In a typical jobbing shop, the throughput of existing moulding presses may be increased threefold by their use.

Another application in which dielectric heating equipments are finding increasing use is in the manufacture of furniture and plywood. Glue is extensively used in both these manufactures, and the quality and speed of production of glued joints can be significantly improved by the use of thermosetting glues, particularly if the glue can be heated without heating the wood. The dielectric heater is uniquely suited for this latter purpose.

The manufacturers of glues have recently developed glues having a high dielectric loss to facilitate the method of production, and a large proportion of the furniture made in this country now uses these techniques.

Fig. 2. 1 kW dielectric heater with cover raised to show the plate electrodes.

Photoelectric Devices

Photoelectric relays which operate when a beam of light is interrupted or restored are widely used for simple applications such as burglar alarms, machine guards, counting articles, detecting pin holes and automatic gauging etc.

A grinding machine fitted with photoelectric sizing control, as already mentioned, is shown in Figs. 3 (*a*) and 3 (*b*); press guard protection in Fig. 4, and a shear and twist machine operated by photo cell in Fig. 5. The latter application is a good example of precision timing using electronics and will be further considered.

It is necessary in a certain rod mill for the billets to have an accurate leading section immediately before insertion into the dies of the next stage, but as a result of previous rolling, the leading end of the billet becomes splayed, and this part has to be sheared off to restore an accurate cross section. Since the billets may be moving at speeds up to 14 feet per second, and are spaced at only one foot intervals, the shearing operation has to be performed in the short time of one fourteenth of a second. The timing of the shearing operation is carried out by a thyratron timing device which is actuated by a photoelectric cell placed 10 feet ahead of the shears, and working off the infra-red radiation of the hot billets. After shearing, the rod passes immediately along an open channel which is rotated at the appropriate instant under the action of the thyratron timer, thus ejecting the rod which drops to the floor in a loop, and giving it a twist before insertion into the dies of the next stage.

In a slightly more refined form the photo-cell can be used to distinguish between different colours or degrees of brightness, and are so used in sorting and

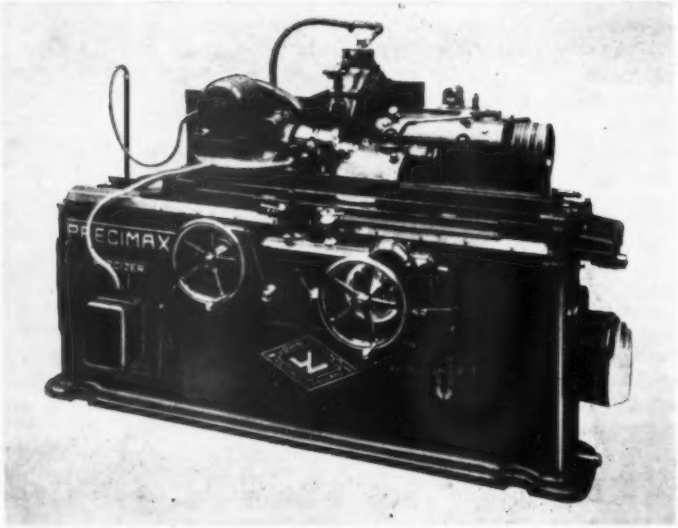

Fig. 3(a). Grinding machine fitted with photoelectric sizing control.

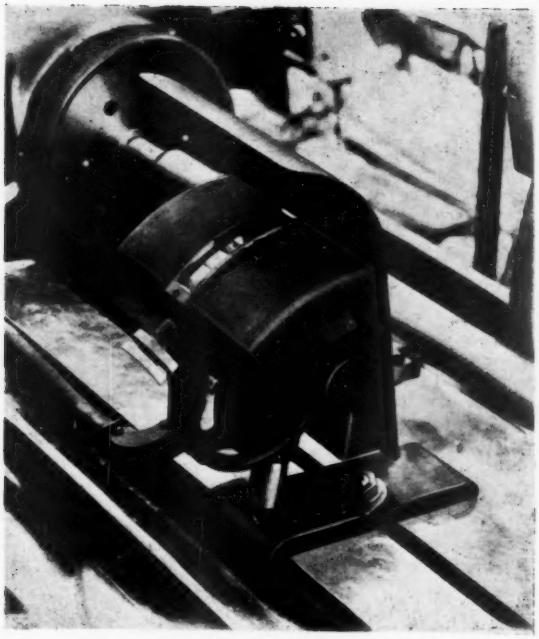

Fig. 3(b). Close-up view of measuring head.

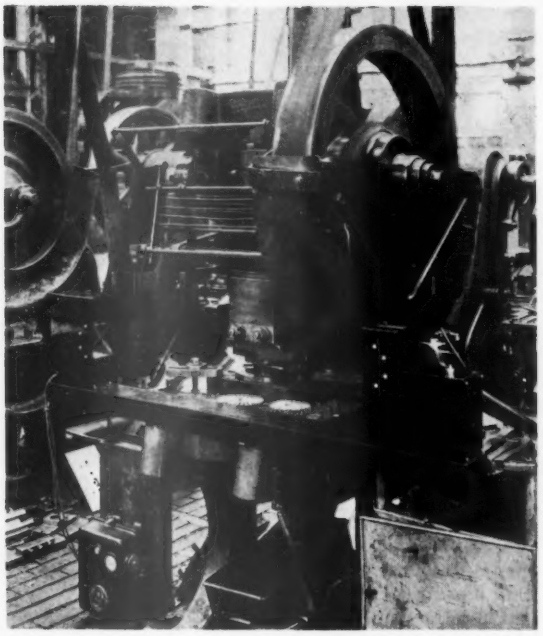

Fig. 4. Photoelectric protection of press tool.

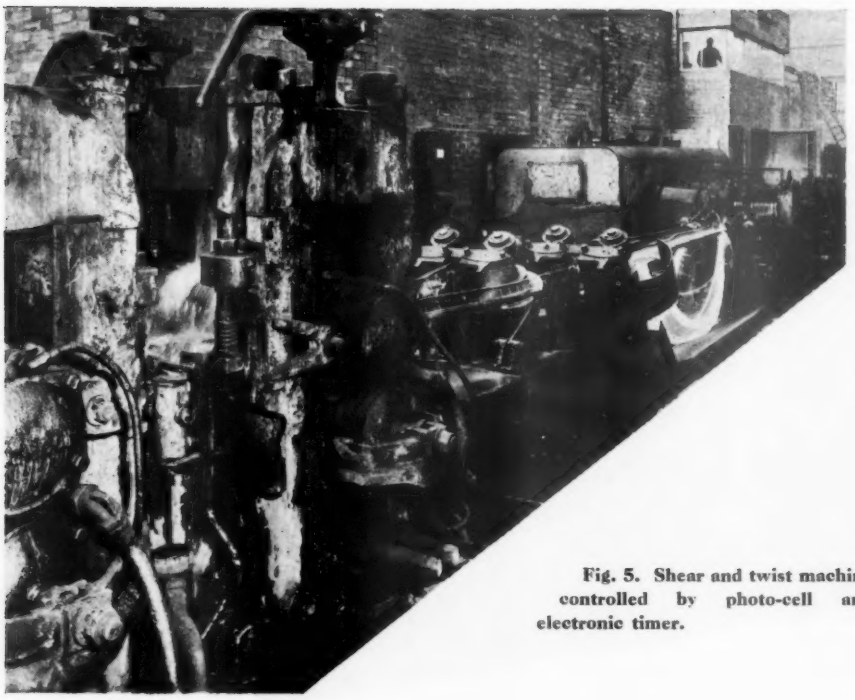

Fig. 5. Shear and twist machine controlled by photo-cell and electronic timer.

Fig. 6. Batch counting of cycle components.

grading applications. One automatic pea sorter can distinguish between green and discoloured peas at a rate of some thousands per minute.

Photoelectric cells are also used as the error sensing elements in equipments for "edge guiding", *i.e.* controlling the lateral position of the edge of a continuous strip of material as it passes through a machine. The guiding of cloth into a tentering machine is a good example of the use of this form of control.

Equipments using photoelectric cells are also in widespread use in the paper and printing industry, for keeping the printing and cutting processes in step, using a photocell to view printed marks on the paper. Such equipments soon repay their cost in the reduction of spoilt products.

Batch Counting

There are many applications in industry for counting articles or component parts in batches and quite often a control signal has to be made available on the completion of a pre-determined number of counts. An example of this is shown in Fig. 6, where a batch counter is being used to count out cycle components. A standard size of box is used, and the batch counter is set up by the operator to count out the number of parts which the box will hold. On completion of the count, a control signal automatically stops the

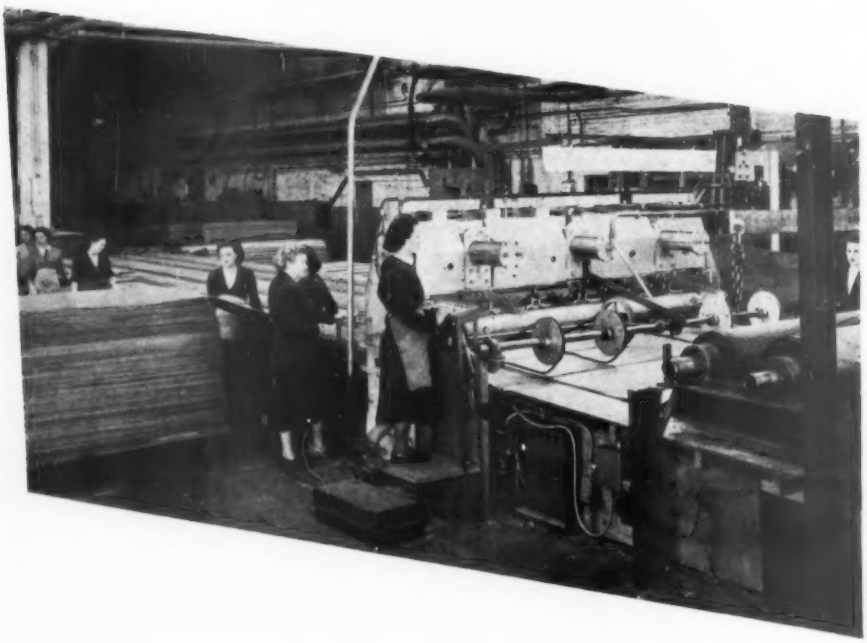

Fig. 7(a). General view of veneer clipping machine.

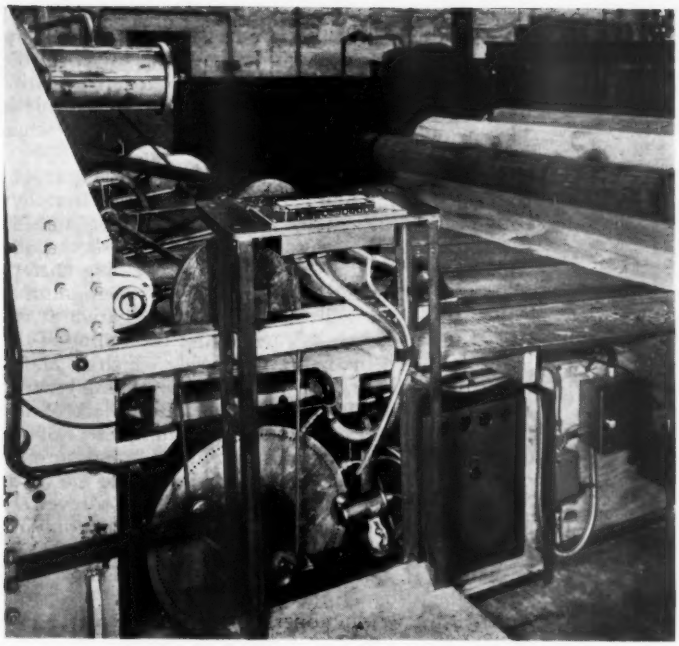

Fig. 7(b). Close-up view, showing the disc, photo-cell, push-button control and Dekatron counter.

conveyor and the table holding the boxes is indexed round to the next empty box.

A more recent, and less common, use of batch counting is for measuring lengths of veneer. A general view of a veneer clipping machine can be seen in Fig. 7 (*a*). The movement of the veneer towards the clippers is transmitted by a friction drive to a large disc having equally spaced holes around its periphery. A photo-cell mounted near the disc monitors the holes passing it and a count of the number of holes is made by an electronic counter. The drive to the disc is so arranged that ten holes pass the photo-cell for a one-inch movement of the veneer, thus enabling the counter to register the length of veneer in inches and tenths of an inch.

A close-up view of the disc, photo-cell, push button controls and the Dekatron counter is shown in Fig. 7 (*b*). The length of veneer is pre-determined by plug connections inside the Dekatron counter, it being possible to set up six different lengths, any one of which may be selected by push button. On pressing a button corresponding to a particular length, the machine will operate continuously, clipping identical lengths of veneer.

Speeds up to 130 feet per minute can be achieved, this representing a five-fold increase over previous methods, and cut lengths can be maintained to an accuracy of plus or minus $\frac{1}{4}$ inch. The cost of the electronic control was saved in four weeks.

Resistance Welding

Resistance welding is the process whereby two pieces of metal are raised to welding temperature by passing a large electric current through the junction of the two, the actual weld being completed by mechanical pressure when the metals are hot enough. It is generally agreed that electric resistance welding is one of the most rapid methods of assembly known.

The general process has been known for very many years, but the advent of electronic control has improved the quality, consistency and speed of the process to such an extent that it is now in universal use, and has spread to many fields in which the requirements of operation could not be met in the pre-electronic era.

In order to obtain the large welding current at a low voltage from the public A.C. supply, a welding transformer is used, and control of the welding current is exercised by control of the primary current in the transformer.

The major contribution of electronic control to the process lies in the method of controlling the primary current. The mechanical or electro-mechanical contactor previously used has several defects, the principal ones being slow speed of operation, inadequate consistency of operation, mechanical wear and deterioration of contacts, and difficulty of ensuring opening and closing of the contacts at consistent points in the cycle of voltage. All these defects are overcome by replacing the mechanical contactor with an ignitron contactor.

A sectional view of a 140 amp. ignitron can be seen in Fig. 8 and gives some idea of the general construction. Basically the ignitron consists of a graphite anode, a mercury pool cathode and an ignitron which dips into the mercury pool, these elements being enclosed in a glass envelope which is itself surrounded by a water cooling jacket. The ignitron can be regarded as a heavy current switch capable of carrying current in one direction only when "switched on" by

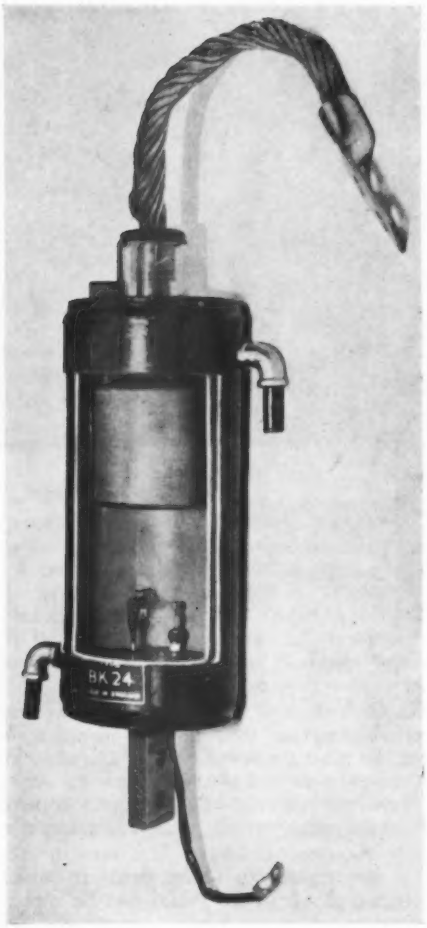

Fig. 8. Sectional view of ignitron, showing general construction.

passing current into its ignitor. Once current has been established in the ignitron it continues to flow until the anode voltage is made negative to the mercury pool cathode, when the current is extinguished. The ability to break the current cleanly is thus an inherent characteristic of an ignitron when used in A.C. circuits.

In order to carry alternating current, two ignitrons connected in opposite senses are necessary so that they conduct current in turn as the voltage alternates. If the voltage to the ignitor is applied as a short pulse while the ignitron anode is positive, welding current flows from the point in the cycle when the ignitor is pulsed until the ignitron anode goes negative at the end of the half-cycle. Variation of the timing of the ignitor pulse in the half-cycle during which its anode is positive will vary the value of the welding current and hence will also vary the heating effect of the current. Further control of the heating effect of the current can be obtained by varying the total number of half-cycles in which current is passed into the weld.

The ignitron contactor comprises a pair of reversely connected ignitrons with a simple circuit for supplying the ignitors with current when an external contact is operated. It can be regarded as a straightforward replacement for the mechanical contactor.

When the welding operation requires more precise control than can be given by a simple externally controlled contact, an automatic welding equipment is used. The simplest of these is a spot-welding equipment comprising an ignitron contactor with an electronic timing or control circuit to permit a predetermined and adjustable number of cycles of current to pass when the operating switch is closed. A control of this type is shown in Fig. 9, in conjunction with a deep throat welding machine. As welding progresses along the steel cylinder, a closed loop of metal is formed around the heavy current conductors, giving rise to an inductive volt drop which would reduce the welding current. A special feature of this controller is its ability to maintain constant welding current irrespective of the variable electro-magnetic loading caused by the formation of closed loops in the workpiece.

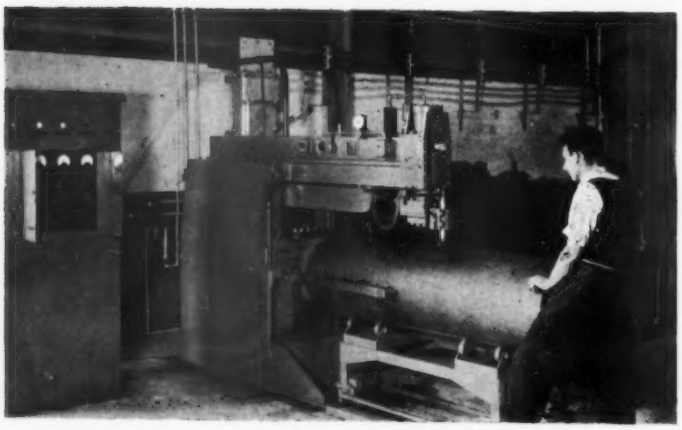

Fig. 9 Deep throat machine with spot weld control giving constant current.

The addition of a control which varies the timing of the ignitor pulse in each half-cycle greatly increases the versatility of the device, as the intensity of the welding current can be controlled independently of its duration.

The precision of control of the welding current obtained by these methods is far in advance of anything attainable by human judgment, and shows a considerable advance in consistency and freedom from trouble over mechanical devices such as dashpots. The resulting welds are consistent, and when the control settings have once been determined for the job in hand, the results can be repeated at any time without difficulty.

When one or both of the pieces of metal to be spot-welded are rather thick, there is considerable risk of burning the outer layers of metal which touch the welding machine contact tips, before the junction of the metals has risen to welding temperature. This can be prevented by applying the current in a series of "shots", allowing brief intervals between shots for the heat to spread through the metal.

This form of control is known as pulsation or woodpecker welding, and requires an extension of the timing facilities to control the duration of the intervals (cool time) and the number of shots per weld (heat time) in addition to the duration of each shot. For many years controls of this nature have been designed around the time discharge properties of a capacitor and resistor, but quite recently a more elegant solution has been found in the use of Dekatron counter tubes.

The Dekatron counter, which is a glow discharge tube, is used for counting pulses and it has great merit in directly providing a display of the count. A single tube can be used as a 10-position register, each pulse causing the glow to move one position clockwise. With suitable circuits it is possible to select counts from 1-10 on a single tube by turning a switch, the counter automatically re-setting and producing an output signal at the end of the selected count. Time pulses are very conveniently obtained from the 50 c/s mains supply and the Dekatron therefore counts in 1/50 second units or more simply, in cycles. By using two Dekatron counters to control respectively the "ON cycles" or heat time, and the "OFF cycles" or cooling time, complete control of the welding cycle can be obtained.

A combined spot and seam welder control equipment using Dekatron counters is shown in Fig. 10 (*a*).

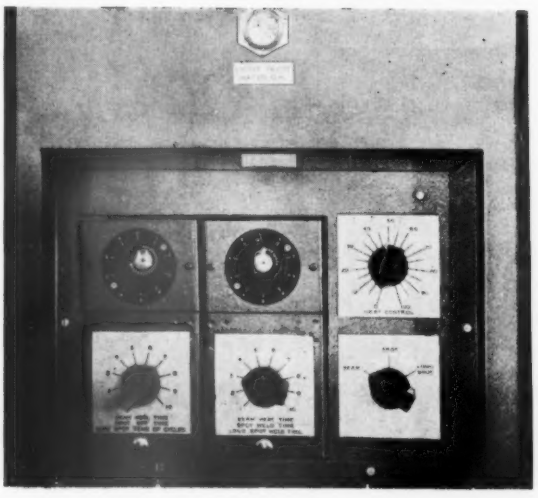

Fig. 10(a)—*top, right.* Spot and seam welder using Dekatron counters. Ignitron contactors are housed in lower part of cubicle.

Fig. 10(b)—*below, right.* Close-up view of Dekatron counters.

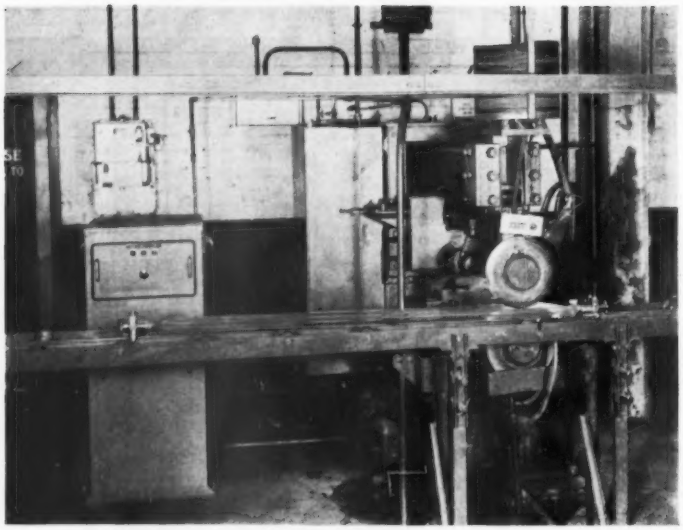

Fig. 11. Modern seam welder.

The welding cycle is set up by switch selection of the requisite number of "ON" and "OFF" cycles respectively, the range of each control being 1-10 cycles. For longer welding times there is a "LONG SPOT" control which covers the range 10-90 cycles. The close-up view of the Dekatron and controls in Fig. 10 (*b*) shows clearly how the welding cycle is displayed.

When the work commences to heat up as welding current flows, it softens and the pressure of the welding tips causes some indentation of the metal. Until this deformation is completed and the tips are properly bedded in the metal, the electrical contact between the tips and work is of a variable nature and may give rise to "splashing" or minor local burning around the tips. This does not greatly affect the quality of the weld, but seriously reduces the life of the tips.

A circuit addition known as "slope control" ensures that the welding current increases from a low value during the first few cycles, allowing the tips to bed before the full welding heat is applied. This additional control has been known to increase the life of welding tips tenfold.

Programme control welding equipments, an example of which is seen in Fig. 12, have provision for varying both the value and duration of the welding current for each weld in accordance with a pre-set programme. These more complex controls have made possible the welding of many alloys previously considered intractable.

A disadvantage of resistance welding operations is that heavy, intermittent single-phase loads are imposed on the A.C. supply. Where the economics of the case justify it, three-phase equipments may be used. These take a balanced load of good factor, but are more complex than the single-phase equipments, and consequently more expensive.

Fig. 12. Programme welding machine for the assembly of aluminium alloy cowlings.

Electronics as Part of a System

General

The electronic devices already dealt with may be described as additional aids to a process, but it is not uncommon to find electronics engineered into a sequence of a process, as for example, in conveyor and sectional drives.

Attention will be confined to applications in which the electronic device is controlling a motor, as these occur very frequently, and embracing as they do, the expanding field of machine tool drives, are extremely important to the production engineer.

Standard Motor Controllers

Standard equipments are available for controlling motors from $\frac{1}{2}$ to 600 h.p. rating. D.C. motors are generally used, speed control being effected by the separate or combined variation of either armature voltage or field excitation, giving an infinitely variable speed change over the required range. The D.C. power for the armature is obtained from a converter working on commercial A.C. supplies, conversion being either by static rectifier or motor generator set. With the latter form of converter, it is usual to employ a Ward-Leonard control of the motor armature power. Both forms of conversion permit the main flow of power to the motor to be controlled by a much smaller power which can be supplied conveniently from hard valves and thyratrons.

The form of static rectifier used depends on the motor horsepower to be controlled. In equipment for supplying motors up to 40 h.p. rating thyratrons are used; higher ratings of 50 to 600 h.p. are supplied from ignitrons. An example of a thyratron equipment is shown in Figs. 13 (*a*) and (*b*), which is a 3 h.p. wall-mounting panel.

The two thyratron rectifiers are placed in upright positions at the edges of the panel and the field rectifier valves and control valves are mounted horizontally between the thyratrons. A control equipment for 350 h.p. is shown in Fig. 14.

Power conversion from A.C. to D.C. is carried out by six water-cooled ignitrons mounted in the right hand compartment. The main incoming and outgoing connections and the A.C. circuit breaker are housed in the centre section. The left hand compartment contains an upper armature control panel, a

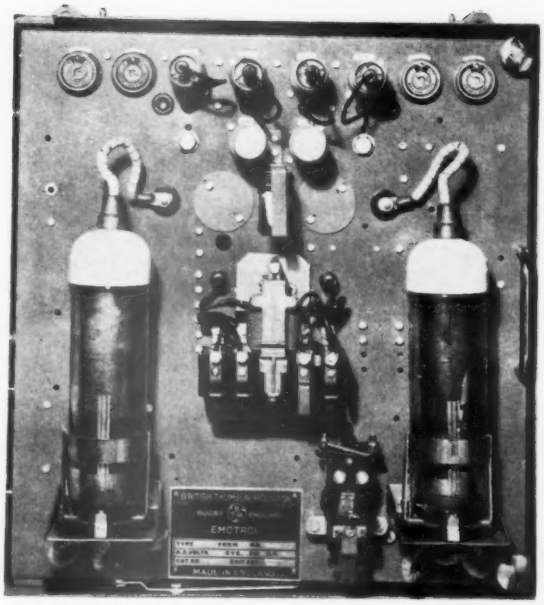

Fig. 13(a). Standard thyratron motor control panel for 3 h.p.

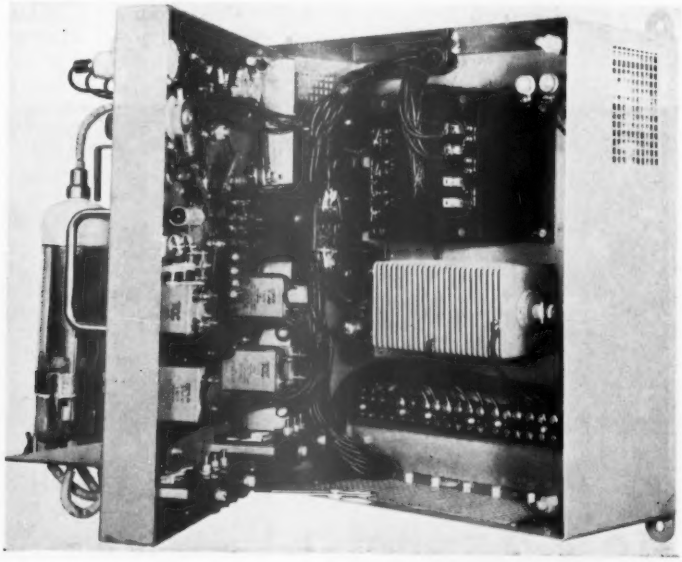

Fig. 13(b). Standard thyratron motor control panel for 3 h.p. with the front panel open.

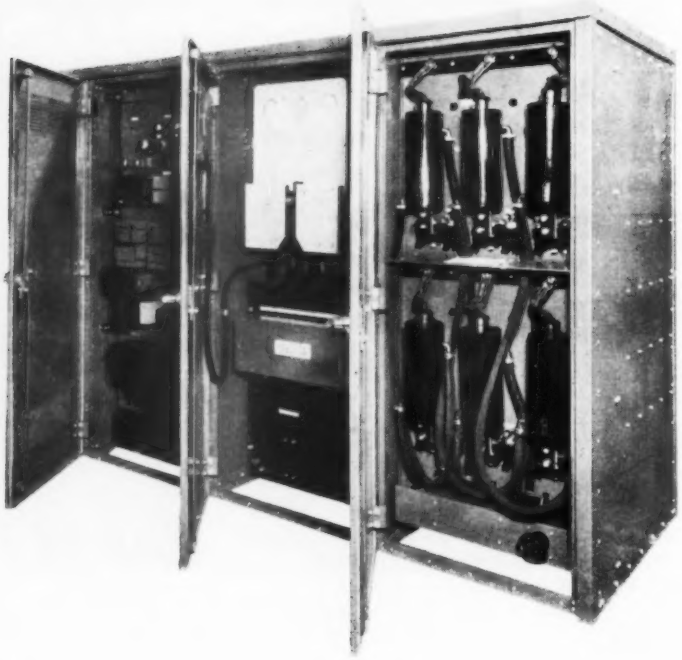

Fig. 14. Ignitron motor control equipment for 350 h.p.

central field control and a lower panel which carries a motor-operated speed control potentiometer and auxiliary supply transformers. When wide speed control is required in a machine tool, electronic control offers a neat and compact solution, and it is possible to accommodate the electronics within the machine as can be seen in Fig. 15, which is a grinding machine controlled by thyratron rectifiers.

For straightforward speed control, an error signal is obtained from the difference between a reference voltage selected manually by a potentiometer and a voltage proportional to speed which is derived from the armature circuit of the motor, or from a tacho-meter generator coupled to the motor. The error signal, after suitable amplification, is used to control the flow of power into the motor which responds in a manner which reduces the error. In order to get an output from the power controller, it is always necessary to have a small error signal and, therefore, there is always a small difference between the potentiometer voltage and the tacho-generator voltage. However, the difference is so small that overall speed accuracies of 0.5% of full speed can easily be achieved from no load to full load.

The motor is fully protected from overload by a current limit control which limits the value of arma-

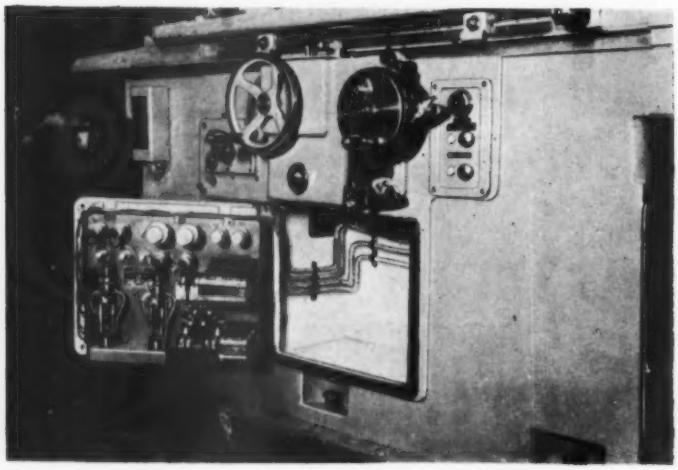

Fig. 15. Grinding machine with built-in thyratron panel for speed control.

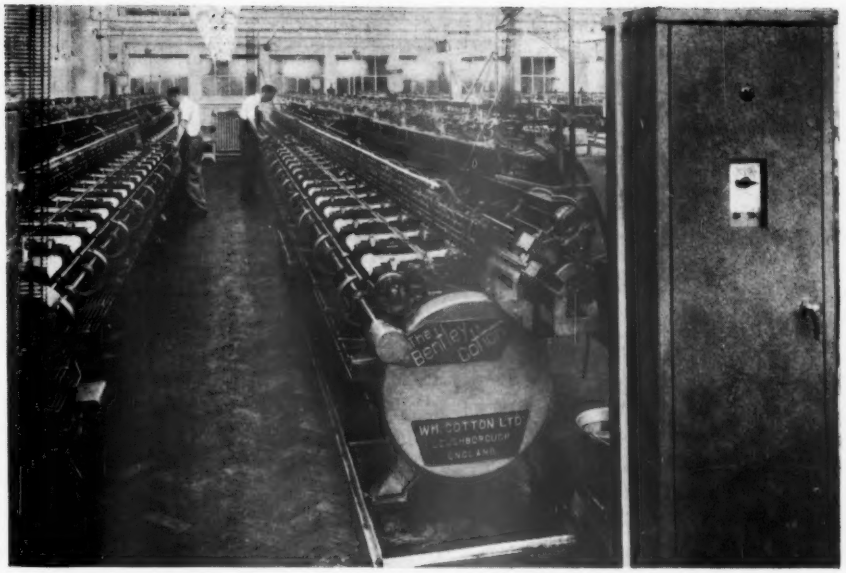

Fig. 16(a). Stocking knitting machine with variable speed control using thyratrons.

ture current to that which the motor can safely withstand. Good power factor and high overall efficiency can be readily achieved. The electronic regulator is also very flexible and a motor may be controlled to give different characteristics such as constant speed, constant torque or constant horsepower by virtue of the closed sequence of control.

Special Applications

In hosiery manufacture it is necessary to operate the knitting machine at several pre-set speeds in a sequence determined by the progress of the article being made. A 3-phase thyratron rectifier equipment rated at 5 h.p. for controlling the speed of a fully-fashioned stocking knitting machine is shown in Fig. 16 (*a*). The required speed of operation is determined by cam-actuated switches within the knitting machine and these in turn select appropriate pre-set speed potentiometers in the control cubicle. A close-up view of the control cubicle (Fig. 16 (*b*)) shows the six pre-set speed potentiometers on the left hand side. The control amplifier is situated at the top of the cubicle and further down the three thyratrons for supplying armature power can be seen, with the field rectifier valves mounted immediately underneath them.

A further example of the electronic control of motors is in sectional drives for paper making machines, this form of control representing a notable advance in the method of driving such machines. In a 17-section paper machine, each section is powered by a D.C. motor with constant field excitation and Ward-Leonard generator control of the armature. Each motor has its own generator which is excited by grid-controlled thyratron rectifiers. The individual driving motors with tacho-generators and some of the

Fig. 16(b). Close-up view of control cubicle for knitting machine.

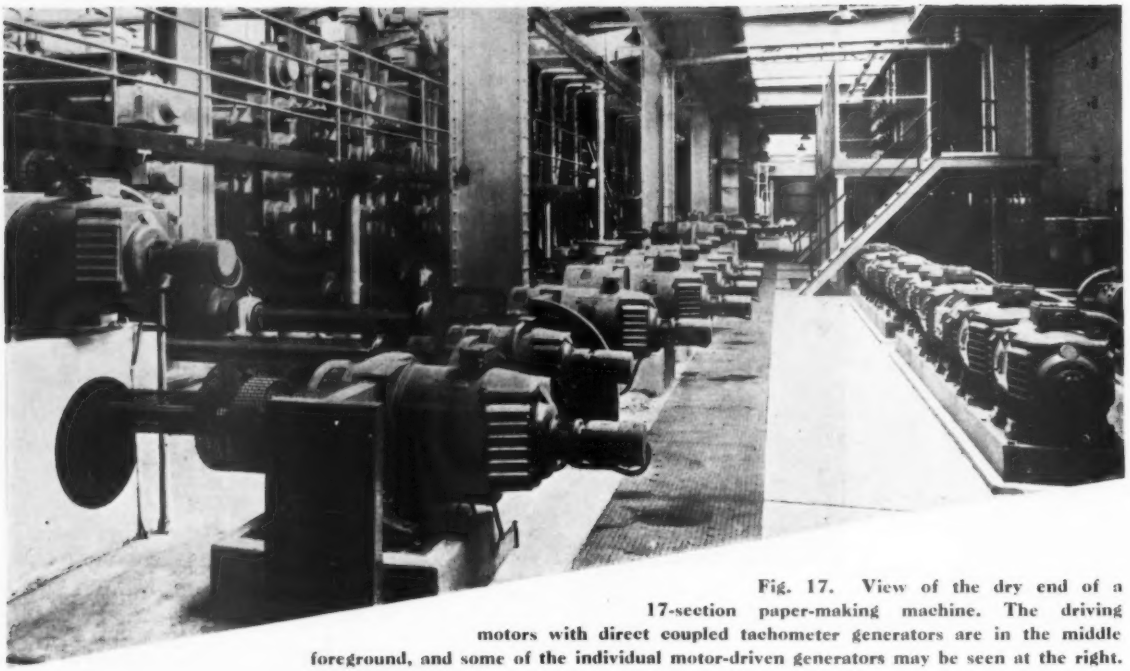

Fig. 17. View of the dry end of a 17-section paper-making machine. The driving motors with direct coupled tachometer generators are in the middle foreground, and some of the individual motor-driven generators may be seen at the right.

motor generator sets can be seen in Fig. 17, which is a view of the dry end of a 17-section paper making machine.

The difference between the tachometer voltage which is a measure of motor speed, and a reference voltage representing speed, is amplified and applied to the grid-controlled rectifiers supplying the generator field. The closed sequence of control, coupled with high amplification ensures that the difference or error voltage is maintained at a very low value. No moving parts are involved in this speed regulating system which is therefore free from inertia effects, giving rapid response and freedom from mechanical wear.

The operating speed range is from 40 to 400 feet per minute and the regulation is such that the speed change due to all causes is less than 0.1%. Fig. 18 is a general view of the electronic control gear.

There are many more applications for electronic control of motors but only brief mention of these can be made. They include motor control in newspaper printing presses, wind tunnel fan drives and spindle speed control in the ring spinning of cotton, etc.

Machine Tool Control

General

The advance of electronics into the machine tool field has only recently become marked, but the rate of expansion in this field is now high. On small horsepower drives where a wide speed range is required, electronic control offers a cheap packaged system giving an infinitely variable choice of spindle or feed speed, with small neat controls which can be housed anywhere on the machine or separately. The motor is usually inherently protected against overload, and has good speed regulation over the whole working range.

The wide speed range can often eliminate much gearing. Interconnection of the spindle and speed circuits can also eliminate long shafts and lead screws for giving feed rates related to the spindle speed. On very large machines, the concentration of many small controls into a single control station can save much of the operator's time in operating the machine.

Feed rates can readily be controlled to maintain constant load on a milling cutter or grinding wheel, thus maintaining the machining conditions at their optimum, and raising machine productivity. If maximum production is to be obtained from lathes and boring mills on facing cuts, the headstock or table speed must be increased as the tool moves towards the centre of rotation in order to maintain constant cutting speed, and hence optimum cutting conditions. The time to complete a facing cut can be reduced by 30% to 40% in this way.

For multiple operation applications in which a number of different spindle or feed speeds are required in succession, electronic controls offer simple and cheap methods of setting in any chosen number of pre-set speeds which can be selected manually on a small multi-way switch, or set-in in succession automatically as the machine completes each operation.

Copying Devices

As visitors to recent machine tool exhibitions will have seen, there is now a considerable range of

machine tools available fitted with devices for reproducing a machined part in accordance with the shape of a master template.

Of the copying devices used, the majority control one only of the feed motions of the machine, and are known as "single dimension" copying equipments. They have a wide field of application in lathe work for the production of parts such as shafts with steps and tapers, and can bring about considerable reductions in machining time. The majority of such equipments are hydraulically operated, and for the general quality of work required, electronic controls have difficulty in competing in first cost. Electronic controls can however offer better accuracy of control than can be maintained with all-hydraulic equipment, and are much more adaptable to applications a little different from the usual run.

Fig. 19 shows an electronically controlled copying lathe set up for machining eccentric workpieces. The electro-magnetic tracing head and the template appear in the middle foreground. The cross slide carrying the milling cutters and tracing head is moved by a feed motor under automatic control to keep the stylus in contact with the template, which is rigidly connected to the rotating workpieces; a constant feed is applied to the lathe saddle. This equipment will maintain a controlled feed of 60″ per minute, with a change in stylus deflection of only 0.001″. With such a high sensitivity, rapidly changing contours can be machined accurately.

There are, however, many contours which cannot be machined by the automatic control of one feed motion only and it is necessary to control two motions simultaneously. Electronic controls are much more competitive in these more complex applications and are now used for operations such as milling out aircraft spars of continuously varying thickness and cutting irregularly shaped holes. It is important to note that two and three dimension control cannot be obtained by simply adding separate automatic tracing feeds to the second and third motions; unified control of the feed motions is necessary.

In a two-dimension system there are two feed motors, giving separate drives to the two feed motions which are generally at right angles to each other. Fig. 20 illustrates a tracing head in which a stylus responds to deflections parallel to the two feed motions and produces a control signal proportional to both the amplitude and direction of stylus movement. The control signal operates on suitable circuits driving the two feed motors such that a constant working deflection is produced at the stylus which moves tangentially along the template. The working deflection, which can be selected on the equipment to be from 0.005″ to 0.04″, depending on the application, can be allowed for by making the radius of the stylus greater than that of the cutter by the amount of this deflection.

The accuracy of copying is very dependent upon the mechanical condition of the machine tool and the feed speed used. Maximum errors of the order of .004″ can be achieved on slowly varying contours

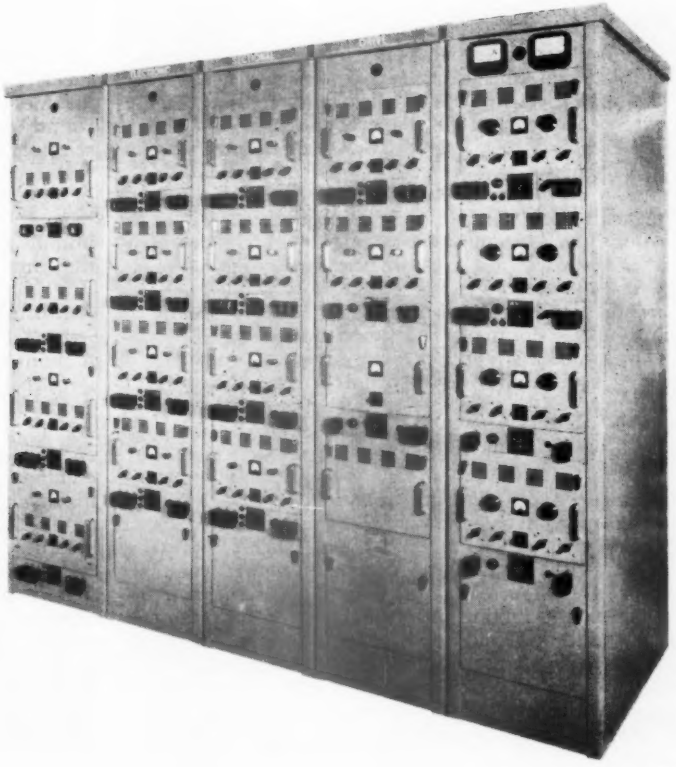

Fig. 18. General view of the electronic control equipment for the 17-section paper-making machine.

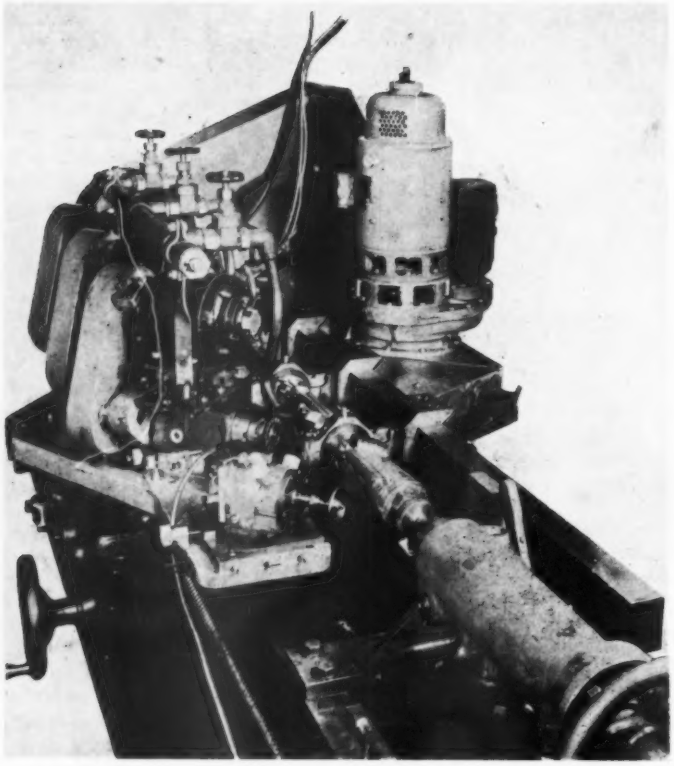

Fig. 19. Electronically controlled copying lathe set up for machining eccentric workpieces.

with feed speeds around 12″ per minute. With careful design, the errors can be reduced to about .001″ at a feed speed of 2″ per minute, the actual figure depending on the shape of the contour to be followed. Higher speeds of 60″ per minute or more can be achieved, and the error may be held to .005″ or less for a gently curving contour.

Machines are available in which the path of the cutting tool is controlled by photo-electric means from a drawing of the required contour. The accuracy attainable is lower than with a solid template, this type of control being commonly used on flame-cutting equipment cutting boiler plate.

Three-dimension control is necessary for die-sinking operations; two perpendicular axes to trace the contour of the cross-section of the master template, and a third mutually perpendicular axis to apply an incremental feed on the completion of each pass in the contouring axis. Small workpieces may be machined on either vertical or horizontal machines, but the more massive forms are generally machined on horizontal millers, an example of which is shown in Fig. 21. It is possible to select either a vertical or horizontal contouring plane to suit the work in hand, or the depth motion may be cut out to permit profile milling of interior or exterior shapes in the vertical plane. The two- and three-dimension equipments just described are also fitted with a "steering" control which enables the operator to guide the tool to any part of the workpiece so long as the stylus is not in contact with the template. When the stylus meets the template, the tracing head automatically assumes complete control and contouring commences round the template in one of two directions as selected by a switch.

A recent development allows all three motions to be under contouring control, but as the system must have built-in means of deciding in which of the infinite range of possible directions it shall proceed, the control scheme becomes rather complex.

Automatic Machine Control

In a copying device, the information governing the motions of the machine tool is in a simple mechanical form representing directly the shape of the machined product. Automatic control has been carried beyond this to a point where the required information is contained in magnetic tape or punched card form, eliminating the template and tracing head, and making the change of machine set up from one job to another as simple as changing a gramophone record.

The most straightforward system of this type uses a normal machine tool which may be fitted with contouring attachments, but has in addition small electric machines, of the type generally termed "synchros" fitted to each motion.

The machine is made to perform all the necessary operations to complete the machining of the workpiece, the signals from the synchros being recorded

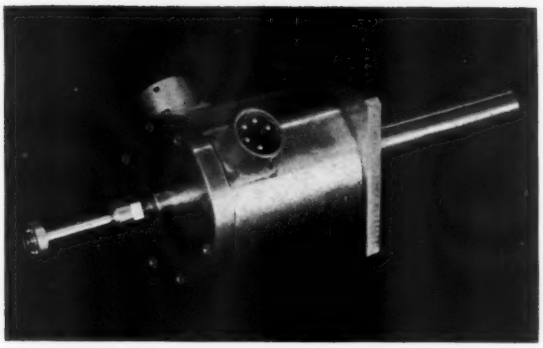

Fig. 20. A two-dimension tracing head.

on magnetic tape. The tape now becomes the master record of the process, which can be repeated at any time by a "slave" machine which is also fitted with synchros, the slave being controlled electronically so that its synchros repeat all the motions previously carried out by the synchros on the master machine.

Another machine recently demonstrated in the U.S.A. uses punched tape information to control all its functions, the tape being prepared directly from the manufacturing drawings. This particular machine has a number of limitations, particularly in dealing with curves, which must be approximated by a series of straight lines. It can, however, be taken as an example indicating the present trends of development towards rendering the quality of the product independent of the operator's skill and judgment.

Reliability

One of the most important qualities required in equipment intended for use on high rates of production is reliability. Failures must be few, and such faults as do occur should be readily located and corrected. Electronic equipment does not normally suffer from mechanical wear, but care must be taken in the design to ensure that an equivalent trouble, drift in characteristics, does not become sufficiently pronounced to entail frequent re-adjustment of the circuits.

The performance and reliability of electronic equipment is judged too frequently on hearsay and second-hand evidence. It is an unfortunate fact that a failure will receive far more publicity than the thousands of hours of trouble-free service which can normally be expected of well-designed equipment of a simple nature. It is to be expected that as equipment increases in complexity, the number of components and hence the rate of fault occurrence will increase, but this is, of course, also true of non-electronic equipment.

The susceptibility of electronic equipment to troubles associated with variations in components is determined as much by the skill and experience of the designer, as by the quality of the components, nevertheless only first quality components should be employed in industrial electronics. Lower grade components will reduce the selling price, but the saving will almost certainly be lost in more frequent outages for re-adjustment or correction of faults.

Fault Location

The provision or omission of built-in monitoring equipment is largely a matter of economics. Generally on small equipments where the market is highly competitive, such additions are reduced to a bare minimum. As equipments increase in complexity, the case for monitoring becomes stronger, but the determining factor is always economic.

In applications in which shut-down time is very expensive, extreme measures are sometimes taken to ensure that any failure will result in the faulty section being removed from the circuit and replaced with a spare section. Complex equipments can usually be broken down into functional groups of circuits. It is good design practice to ensure that such groups are readily distinguished one from another in the mechanical assembly, and to make provision for the testing of individual groups. This usually means that provision must be made for breaking into the connecting circuits.

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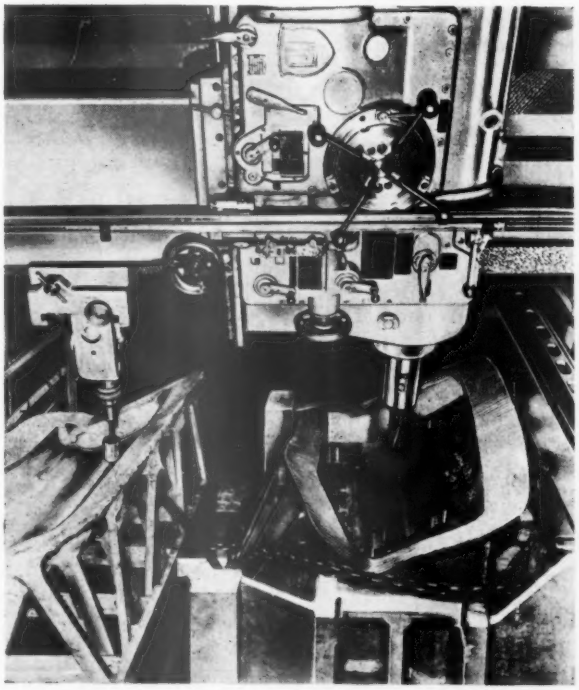

Fig. 21. Die-sinking on a horizontal milling machine fitted with three-dimenson tracer control.

DOES THE HIGHER NATIONAL CERTIFICATE IN PRODUCTION ENGINEERING MEET THE NEEDS OF INDUSTRY?

by J. V. CONNOLLY, B.E., M.I.Prod.E., F.R.Ae.S.,

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Presented to the London Section of the Institution, 24th February, 1955.

I AM well aware that this is a controversial question to which a categorical answer cannot be given, but it is my opinion that if the present Higher National Certificate in Production Engineering *does* satisfy the needs of industry, then industry is taking a very short and narrow view of the whole subject.

In order to support my opinion, I would ask you to consider the following facts and figures.

Quality of Students

In selecting candidates for the College of Aeronautics, there are interviewed as well as graduates a number of fairly highly-selected Higher National Certificate (Production) students who wish to do post-graduate work on aircraft engineering. Since they are interested in production, they endeavour to join the Department of Aircraft Economics and Production. There are also students who have pursued different preliminary courses prior to coming to Cranfield.

There is thus a good opportunity during the two-year course to make comparisons between the three main streams—first, the University stream, that is, students who have taken an engineering degree and wish to do post-graduate work in the field of production; secondly, students who have pursued technical college studies (or studies leading to an external degree at technical college) in subjects such as mechanical engineering, and thirdly, those who one would naturally expect to proceed to more advanced studies in the field of production engineering—the H.N.C. production students.

Over a period of six or seven years, it has been the general experience at Cranfield to have to refuse admission to a considerable percentage of the H.N.C. (Production) students, who wish to follow this course, because their general educational qualifications are not adequate. In fact, in general, they tend to compare somewhat unfavourably with those who have very nearly the same kind of background and training but have previously chosen to study mechanical or electrical engineering and have taken the appropriate H.N.C.

Experience at Cranfield has also shown that the Mechanical Certificate with production subjects as ancillaries gives a better result than specialisation in the production field throughout the whole course.

There are some people who, from the educational

point of view, will point out another aspect; that the very bright and most intellectual and intelligent students do in fact have a tendency to pursue what they think is the more difficult stream through their college years. They take the Mechanical H.N.C. or Diploma (or the electrical or other similar courses). Thus the people that the Institution of Production Engineers naturally recruits tend to be those who feel themselves unable to—or whose tutors think that they will not—in fact clear the more difficult hurdle and who therefore had better make the best of a simpler course. This is clearly not the best type of student for the most exacting job of bringing up the levels and standards of production in this country. In America the attitude towards industrial engineering is different.

Modern Complexity

This is only one small aspect of the picture, but I shall try to relate it to the whole picture and to give you some other reasons for my opinions.

The field of production engineering is constantly becoming more and more complex. Complexity and the rate of development are, or should be, comparable to purely technical developments. In many cases, the requirements for a man who is to handle these complex problems are not that he should know the way it is done at the moment, or that he should have had lengthy, detailed and intimate experience of current practice. What is required is that he should be equipped to go ahead and do something quite differently from the way it has been done before—that he should know how to tackle new jobs. To my way of thinking, and this is borne out by experience at Cranfield, it is very often the man who has had a wider and more basic training in logical thinking and in the physical sciences who is best suited to handle problems of this kind.

In general, in the past, the production engineer has been regarded as somebody who can deal immediately with a limited range of problems on the shop floor. He has generally been taken from the ranks of the skilled craftsmen who tend to "think with their hands" rather than on paper in a deep logical fashion. This type is not so prepared to throw away what he knows in the search for something in the future, for further development. In this particular instance, the tendency has been to select a man for purely technical reasons rather than for the broader administrative aspects which are becoming the main requirement of industry at the present time.

The training available in the field of production engineering at present gives undue emphasis to purely current and straightforward pieces of knowledge which are not very different from those of a craftsman. As time goes on, the amount of thinking of this type which is required will diminish (or at least its importance will diminish). I do not think we have faced, as yet, in the stream of Higher National Certificate students, the necessity for a wider range of subjects and for better basic training.

For example, in that part of industry which is concerned with manufacturing, which is largely the matter under discussion, more attention should be paid to, and much more emphasis laid upon, the administration aspect, the handling of organisational problems, the financial and personnel aspects, in the training of this particular type of engineer.

It may not be a suitable time to do much about it while a man is at technical college. The task of educating students who can only be released for a limited period during their apprenticeship years, whilst working in a firm, is difficult. One must not, in the circumstances, dilute what *can* be taught to them by including a whole lot of subjects of the administrative type. But we should be deluding ourselves if we were to assume that a man trained for the Higher National Certificate as a preliminary, so to speak, had an adequate basis on which to build, by personal study or by acquisition during his service with the firm, a satisfactory modern standard of industrial engineering or an adequate rate of development to the position where he can be judged fit for modern management.

The word "modern" is used deliberately, because modern management, whether we like it or not, is moving in a different direction to that of our forefathers and, indeed, this is the experience of most of the people who are operating at this time. A good many of the management problems which now have to be settled arise in conditions and contingencies which have not been found in current practice and the experience of the executives in the organisation.

Developing New Methods

There are obviously some fortunate organisations making a product which does not change, or which has small technological content. These can probably proceed on the same form of apprenticeship with people learning the trade in a general way and not bothering too much about other matters. But there are a large number of industries which, to remain competitive with American, foreign and overseas firms (or with the better organisations in this country which have adopted modern technologies) must have the necessary technological brains to develop these new methods. Otherwise, they will soon be in a most difficult and, indeed, almost impossible position.

What I have in mind, of course, are such matters as automation, the utilisation and handling of new materials, and the final "optimization" of the firm's operations as a whole—the integration of the firm's total operations at the optimum point by the use of such techniques as operational research. This requires great knowledge of statistical methods and sometimes of the more advanced branches of statistics. Data must be comparatively accurate so that predictions can be made from limited data (not from years of operating experience) and from a number of other techniques which until quite recently were perhaps regarded by industry at large as somewhat "rarefied" and related to the dim and distant future.

The speed with which some of these new techniques have swept in is already well-known. Those who have had to try and cope with them will be aware of the difficulty of finding anybody who can make a useful contribution in these fields. I would say, categorically, that I cannot imagine a production

engineer could, except in the most limited sense, attain high eminence in the future without at any rate a sound knowledge of modern statistical methods —this is becoming almost self-evident. Yet in most cases this subject is not included in the Higher National Certificate and the mathematics that would form the basic groundwork on which to build are not included in the syllabus. This is a very grave defect.

The Universities are frequently equally at fault—although I am not dealing with them at this moment —in their own courses. But the University student, when he realises the necessity for these techniques (and this is very often after he has graduated) knows enough in general about the disciplines of mathematics and physics and logical thinking to do much of the work for himself and achieve a reasonable standard.

One of the great difficulties of the technical college student, and one which is manifested more noticeably by the production people, is a general tendency to be deficient in the approach to the subject from first principles. They expect knowledge to be provided in the form of question and answer, as in the catechism! No real philosophy is inculcated in the courses. I feel this may be an additional reason why we find that Higher National Certificate in Production Engineering leads to slightly inferior students as compared with the Mechanical. Although I fully agree that mathematics in an advanced form is not a requisite for production engineering in most cases, you can overdo it in the other direction, and possibly we have.

The Quantitative Aspect

Figures are also to some extent significant. In the manufacturing industry in the United Kingdom there are some 60,000 firms employing some seven million people. The firms vary in size from very large to very small, and by no means all these firms require production engineers. But a large number of firms have some people who perform this kind of function. Consequently these firms, who employ these millions of employees, would be expected to require possibly 20,000 to 30,000 senior production engineers somewhere in their organisations. With a number of this sort, the turnover and wastage that must occur due to old age, death, accident, changing jobs and so forth, will amount to a tremendous requirement for people to perform purely production functions, including the wider sense of the word—not actual production on the shop floor, but management, supervision, and later top-level management from the production point of view.

Higher National Certificates and Diplomas produce only about 400 people each year. With endorsements and so forth, the figure is of the order of 500. In the mechanical field, the figure is a great deal higher, of the order of 3,000. These people are mechanically trained and the approach is frankly from the design rather than the operating and manufacturing point of view.

It is well-known that a great many of these people do in fact go quite rapidly into the operating and manufacturing aspects and Fig. 3 gives an estimate of this.

In the mechanical field, which also feeds the production group at this level, there are some 6,000 students who each year obtain the Ordinary National Certificate before proceeding to the Higher National Certificate, or the Production Certificate, in the subsequent period. This gradual whittling-down is not all wastage. By no means all the people who go through the course without getting their Certificates are a dead loss. They have learnt a good deal and have to some extent met the needs of industry.

But the quantitative figures do compare most unfavourably with the same figures for America. I am not in general agreement with those who belittle the average level of the American training in these fields. In America there are tens of thousands of people with training of some sort in these fields*. This greatly exceeds in quantity the figures for the United Kingdom and the best men are of a very high quality.

It is also well-known that the American production engineer, without having the advantage of apprenticeship (to any great extent), does manage to produce virtually all the new production ideas, and if not the ideas, then certainly he produces the machinery and the mechanisms and the practical proof that these new ideas will work. They are then sold to Britain at great cost about five years after they have been current practice across the Atlantic!

This does not seem to be any evidence that the method of approach is wrong, neither does it indicate that we ought to adopt it without change. We are perfectly free to adopt any sensible method to bring about an effective result. But it is my opinion that we are not yet achieving, either in quantity or quality, anything approximating to the real requirements of British manufacturing industry in the field of production engineering.

Some Further Facts and Figures

I would now like to refer to the illustrations to the Paper, which give an idea of the orders of magnitude and add some numerical substance to what I have said.

Fig. 1 is well-known, but it is not specially related to production. I have not been able to extract detailed figures for those who might be regarded as engaged in production research, but it is certain that quite a measurable percentage are actually engaged in production research as well as in purely technological services.

It will be clear that even without accurate knowledge of these figures, we are nowhere near *pro rata* in these matters. The dark shaded area represents research engineers and scientists. An American research engineer or scientist is not one of the people who get their diplomas in "brewing" at the University in 18 months. In these industries, he is usually a man with a Master's degree, or possibly a Ph.D., of a very good University—a man who has done some good work and who has certainly had a sound graduate training in his work.

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* In 1950, degrees awarded:

Business or Commerce	76,500
Industrial Engineering	3,630
Engineering	53,500

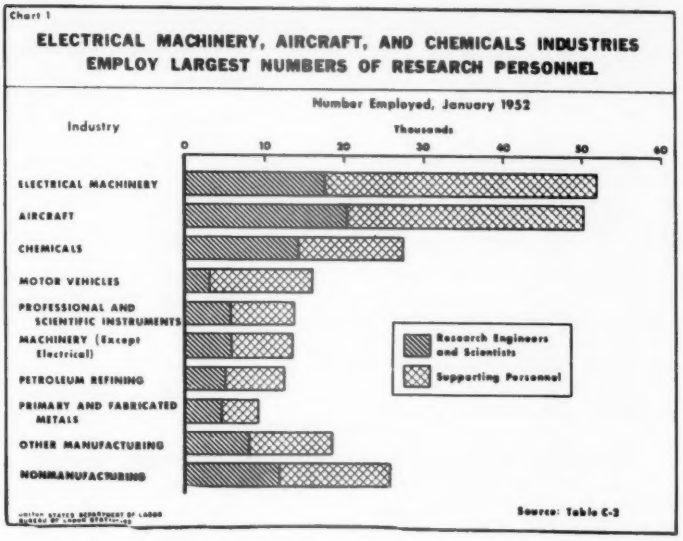


Fig. 1. Research personnel in American industry, excluding atomic energy.

These people occupied in research and science add up to approximately 97,000, which in the United Kingdom should represent the equivalent of about 30,000 graduates engaged on research—many of them would be engaged on production research.

The figures for the aircraft industry are better known to me than those for other activities. In that industry, a firm in America of the magnitude of one of our larger firms—that is, employing of the order of 10,000 to 20,000 people—will have on production research something like 50 engineers devoting themselves to the development of production matters. This is additional to the many hundreds working on aerodynamics, structures, electrical work, and so on, and they will be graduates—not foremen who have the task of getting the job through the shops—but men engaged on real production research.

Firms like Lockheed's and North American have long since put into standard production large slab integral skins which are still only being talked about here, because of the lack of technique and machinery. Our knowledge of it is derived largely from reading American journals. We know it works, and is not merely an academic theory. But on making a start, difficulties immediately arise, many of which could have been foreseen by an 18-year-old apprentice if he had been engaged on a basic study of the problems.

In Fig. 1, most of the industries shown are not like the electrical and aircraft industries (which carry a high percentage of research engineers developing new ideas and methods of a technological nature); a large percentage of the research staff are engaged in research on manufacturing methods in those industries, not in pure research laboratories at all. It will be seen that these industries have over 50,000 men engaged in research.

Fig. 2 comes from "Fortune". It indicates the percentage of American University graduates by various faculties. The heavy black line going across the graph almost diagonally upwards represents business and commerce graduates. It includes those who do industrial engineering and business administration and its related subjects.

The line going down steeply represents the Humanities and Arts, the traditional University subjects. The Natural Sciences have generally

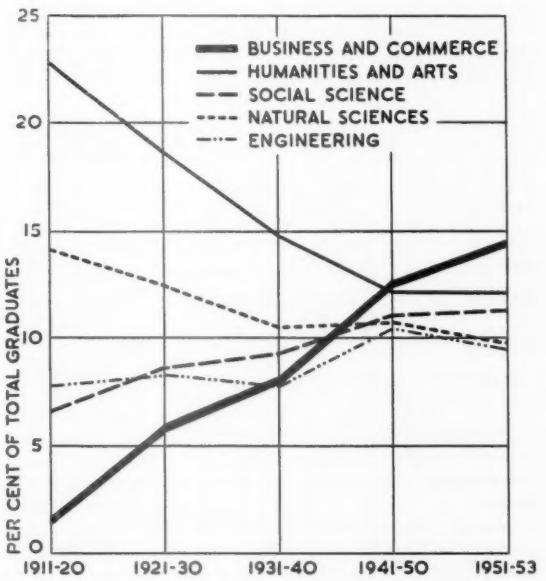
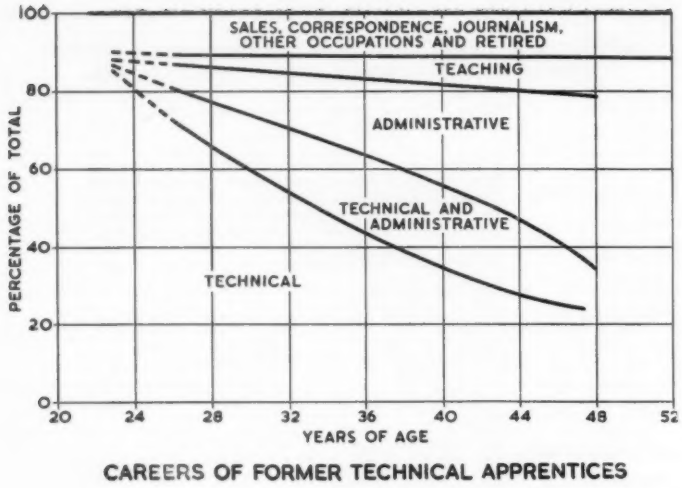


Fig. 2. The distribution of students in faculties in American Universites.



CAREERS OF FORMER TECHNICAL APPRENTICES

Fig. 3. Careers of technical apprentices indicating subsequent transfer to administrative work.

tended to go down, and Engineering in the technical sense has only just held its own, in spite of the insistent demand for engineers for research and development as well as for ordinary operational work and the professional engineering activities. It will be seen that consistently and steadily there has been a growth in the percentage of those who consider that training in business and administrative functions is well worth while.

Fig. 3 indicates roughly the history of the technical engineer. The figures are only general, and do not have any great accuracy, but they show what happens in subsequent years to former technical apprentices who have qualified in one way or another—Higher National Certificate or degree. The assumption is that in general they will qualify at the age of about 23.

It will be seen—and it will probably be agreed that this is reasonable, at any rate qualitatively—that the technical work done by these people diminishes steadily until they are 48. Even if we include those whose administrative work has a high technical content, the same sort of thing happens. Teaching does not attract many. The general group—sales, journalism, and so on—all of which are quite natural and necessary—does not expand very much. The technical training is regarded not as the main issue, but as an advantageous background.

By the age of 48, something like 40% of these people are engaged almost entirely on administrative work, a matter that is hardly dealt with in the syllabus or training of the people in the normal group, starting at the age of 23, under present circumstances.

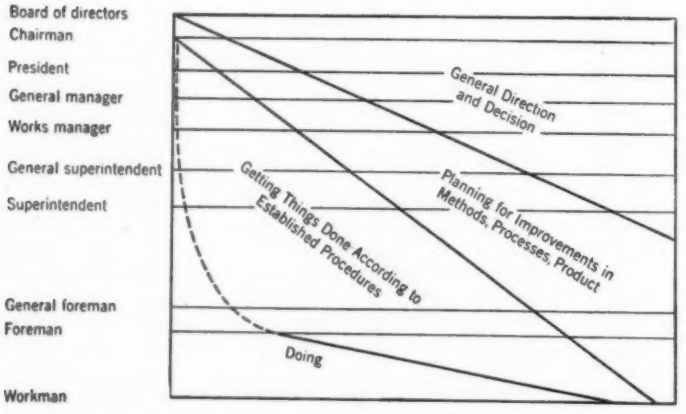


Chart illustrating the division of activities and responsibilities of officers, executives, and supervisors.

Fig. 4. Distribution of duties with age.

Over 60% are no longer on purely technical work.

The trend in Fig. 2 indicates that this 'end' situation has been envisaged earlier in America. There has been specific training for that work instead of intensive training for technical work on which only 25% will be engaged after the first 20 to 28 years.

Fig. 4 shows a similar rough picture of the individual in regard to the distribution of his time. A workman and a foreman spend a great deal of their time doing the job. As they go up in rank, they still spend much time getting things done according to the established procedure. But as soon as they become superintendents, or managers, and from then onwards, 'doing' almost disappears, and planning and the improvement of methods and general direction become more important.

General direction is meaningless without some guiding star. It is essential for a man who is directing to have some intuition or method of arriving at the truth as to where he wants to steer his company or his department for the future. This also applies to planning and the improvements of methods, processes and products.

Such ability does not, as we all know, come naturally. It is probably quite a simple matter; once people realise that they need to be taught how to plan improvements and methods, they can learn remarkably quickly, if they have had general knowledge and experience in their organisations. But for some unknown reason, they just do not do it spontaneously.

Conclusions

I am not sure—because I do not know of any experimental data—whether, if people are taught management subjects early, when they are immature, the knowledge will be retained even though it is not used for a lengthy period. I do not know whether they would have the ability to use, for example, a simple sort of work study outlook, even though in between they have been concerned largely with technological matters; whether they would instinctively apply this knowledge slowly but surely to their laboratory or design or development work. But it is my own opinion that to some extent they will, for one does tend to retain such techniques and I am certain in regard to one important technique—that of statistical approach—that this is so. If one is trained initially in statistics, one will find throughout any other kind of work that it is an invaluable tool. It is one thing I would consider must be given very great consideration when dealing with the question of whether the Higher National Certificate is adequate for industry.

Before I conclude, I would like to make one further point. If people do think that the Higher National Certificate is adequate, against what yardstick are they judging it? Have they ever had, in their organisations, for fair comparison, a man who has been trained differently; shall we say more adequately? Very few people in this country can have had this experience. Therefore the "practical" man who has always been quoted in these matters is the wildest theorist. He is doing exactly what he accuses other people and scientists of doing. He is *theorising* on inadequate data on a subject in which he has not conducted any controlled experiments.

Consequently, I throw back the ball to these 'practical' people and say to them that no matter what their *opinion* may be, if they have not tried the experiment of comparing the man trained by the present methods with a man trained in another manner, then they are theorising.

DISCUSSION

Mr. H. E. Dance (*Ministry of Education*) said the subject was of immense importance. One of the first things to do in considering whether a particular educational service was right for a particular job was to ask the users whether they were satisfied with it and, if not, in what respect. Then one could discover whether, when and how their dissatisfaction could be met. It was really the job of the colleges to satisfy the demand, and the Ministry helped by way of grants.

First, it was important to be quite clear about the terms "certificate" and "diploma". The Higher National Certificate course usually followed a period of three years which began at the age of 16. In that period a boy usually took a Mechanical Ordinary National Certificate. There was no such thing as *the* Mechanical Ordinary National Certificate. There was no one type. The essence of the National Certificate system—and this was significant for the discussion—was that the College set up a course suited to the local requirements, and the local requirements came from the students and from the industries.

One might say at once, therefore, that if any course in any place was not satisfying the local demand, then it was the fault of the industries and the students for not making their demand known. Nobody compelled the students to go into a course, and if the college wanted to change the content of a course, it might do so, provided that the course was not of less than the minimum standard required by the Joint Committee. This was true of all National Certificate Courses.

After he had completed his ordinary course, which

was at the age of 19 plus, the student went on to the Higher National Certificate course lasting two years. These courses had as a minimum standard what could be done in three evenings a week, or roughly seven hours a week for two years for the Higher Certificate.

A boy who took a Higher National Certificate in Production Engineering must first, as a minimum, obtain his Ordinary Certificate in three years.

He might attend in the evening only. On the other hand, it was one of the important developments, on a substantial scale since about 1935, that industry had released apprentices for part-time day attendance at colleges. The student might attend for perhaps seven hours in the day-time, and he might, at his own option, attend on two additional evenings, running perhaps to four hours, so that he put in 11 hours a week. It was clear that there would be a significant difference of standard as between the performance of a boy who had attended 11 hours a week for three years, and one who had attended for only seven hours a week. It was as well to have that in mind. There might be that significant difference of content in either the Ordinary National Certificate or the Higher National Certificate.

Mr. Dance said he would like to draw attention to a difference which was difficult to put over clearly. There were some students whose ultimate objective was achieved when they had reached the Higher National Certificate. They had gone about as far as they could go. They were good men in industry. They were very useful, and normally they were referred to as higher technicians. They were the kind of people who applied known methods. Obviously, they had to use their common sense and, in a limited way, to make analyses and investigations. But in the main the known method was the basis of their actions.

There were other students, and in a way they were the salt of the earth, who attended in the day-time and perhaps on one or two evenings, or even in the evening only, who went on after obtaining the Higher National Certificate for three, four, five or even six or seven years more. They might show a very high intellectual performance. When one came across them, one said what a pity it was they were not picked out earlier and given a better opportunity. These should be in sandwich diploma courses.

In referring to people who had Higher National Certificates, some with endorsement subjects, who had gone on longer, one must expect a great variety of standards. Among them would be the men who had gone on and who often had the qualities of first-class engineers, although they might be deficient in the basic sciences. But they were the kind of men who ultimately overcame their deficiencies, and they were a very important element in the scene.

The term "Higher National Diploma" had been used. Again, there were various kinds. A boy might enter an Ordinary National Certificate course at 16 and being exempted from the first year would serve as a part-time student and as an apprentice for two years. He then might enter a sandwich diploma course lasting four years. Arrangements varied; in some 26 weeks were spent at the college and 26 in industry for each of the four years.

This student attended for 30 hours a week and assuming he had a week off, he would put in 750 hours a year. Clearly, he would put up a much better performance than the National Certificate student. He would not have spent so much time in industry, but he would have done a great deal more work on the basic sciences and other subjects.

Because of the limited demand, there were not very many diplomas, and there were only two or three in production engineering. In fact, there was at the moment no separate award, because one did not set up machinery for only a few courses. But there was an arrangement by which diplomas with sufficient production engineering content were countersigned by the Institution of Production Engineers, and were dealt with by both Joint Committees. This was probably the right solution, because in spite of the extra time, there was a lot more of physics and mechanics, theory of machines, strength of materials and mathematics than production engineering, since these were the bases of good engineering.

He wanted next to touch on a rather sore point about the Higher National Certificate. Before the last War, there was no Higher National Certificate in Production Engineering. The general feeling was—and this was a semi-political question, so one must be realistic about it—that the basis of good engineering, whether production or any other, was good science, good mathematics, good English and good humanities, but not very much of the humanities because there was no time for them in a part-time course: they were learnt on the shop floor. One could see the quandary in which everyone was left. If it was argued that the basis of good engineering was science and mathematics, there was no difference at National Certificate level between mechanical and production engineering. In the time available for the Higher National Certificate, exactly the same course would serve both—taken by different people with different flavours, it was true!

People wanted a Higher National Certificate course in production engineering, however, and in order to get it the argument was put forward that production engineering did not require mathematics. It was a practical sort of engineering. In the early Higher National Certificate, no mathematics as a separate subject was included. It was said that if mathematics was required, it would be done on the way along with the other subjects. But the only way to learn mathematics, for example, in the sense in which one wanted to use it for advanced statistical applications, was by spending time and thought on them.

Mr. Dance said he was not suggesting for a moment that the course was not good. It was excellent for the higher technician and it was a very good thing that there were such courses. But the question he would put to the meeting, in addition to what Professor Connolly had said, was: "Do you still want people trained in that way—higher technicians? Can you make use of them? Are there people who can benefit from that course who could not benefit from some other kind of course?" He would say emphatically that that course was no good whatever for professional engineers for the reason Professor

Connolly had given. It had not enough basic science in it. There was not in it enough time to think in a deep fundamental way. A first-class engineer in production engineering should take the Higher National sandwich diploma course, or a University degree course, if one could be found which included production engineering. There were some such courses. But the Universities had been slow to move for reasons that to them were good ones. They did not quite know how to assess work in some of these awkward new subjects, and they preferred to learn slowly.

In London, at the request of the production engineering industry, three sandwich diploma courses were set up in Technical Colleges. They were still struggling along with not enough students to make them work economically, because the industry was not sure yet whether it really wanted a special course or whether it preferred to take engineers with a broad general basis. The industry ought to think again, and it ought, in Mr. Dance's opinion, to support this type of course which was still on an experimental scale.

He would be glad if Professor Connolly could give numbers in making his assessment of the relative values of the three streams to which he had referred. He himself suspected that it was only a speck of cream floating on the top that was being picked off and sent to Cranfield now and again. It should not be assumed that the jug was full of cream or otherwise.

(The following written comment was received from Mr. Dance following the meeting):

The development of industrial engineering courses in America have some bearing on this matter, but they use the term industrial engineering somewhat differently from our usage here. They have some four year courses in what we should call production engineering of the less mathematical type. These courses start immediately after High School at 18 years of age. There are also industrial engineering courses of one or two years which follow a first degree in engineering which may have some industrial engineering content or not. It is these post graduate courses which provide highly trained people for the American manufacturing industry.

In comparing American and British figures we should bear in mind that in America there are no technical colleges of the type that we know here. The work done in our technical colleges is done in America, as far as what is done there can be equated to our technical colleges, in the universities.

It is interesting to note that about 4% of the total engineering enrolment in America takes industrial engineering. Although we do not run courses which are called industrial engineering, in many colleges here subjects and group of subjects which fall under the same heading are taken and a number of candidates in such courses is again about 4% of the total engineering entry. It is probably true that in the United Kingdom the courses in mechanical engineering, of which at least one third of the content is concerned with production engineering, have about three times as many students as the courses which are labelled production engineering only. The total provision for production engineering education cannot be assessed in terms of the courses which are called production engineering without also taking into account those which may have other names but have substantial production engineering content.

Professor Connolly, in reply, said the definitions given by Mr. Dance — who knew far more than he about these matters — were most helpful.

As regards numbers and the cream, he admitted that the numbers were indeed small. Students accepted in production plus those rejected at the first hurdle (that was to say, on application for admission) were of the order of 20. The mechanicals or degrees were of the order of 30 or so. This made about 40 or 50 in all and what Mr. Dance had said was no doubt true. He himself had detected a big difference in both entry qualifications and later performance in those who had taken the sandwich course leading to a diploma.

Perhaps he had not made it sufficiently clear that the title of his opening address was intended to refer not only to quality but also quantity. The quantitative aspect was in some respects disturbing than the qualitative aspect.

Mr. Fren (*G.E.C.*) emphasised that the Ordinary and Higher National Certificate schemes were narrow not only on the technical side and in the sense that a man had insufficient time for principles. They were also narrow on the non-technical side. The engineer as distinct from the higher technician had surely to be a leader, particularly on the production side. Relationships with the people below him and with higher management were all-important. Non-technical subjects gave a breadth of outlook and a balanced judgment, qualities which were most necessary.

It was not merely a question of whether a production engineer should learn Greek or philosophy or some such subject. It was far more a question of understanding and appreciating non-technical matters and even — say — one or two subjects outside the normal technical scope which could be introduced into the sandwich course.

He hoped other speakers would emphasise the need for encouraging sandwich courses in which time was given not only to further technical subjects but also to the humanities and non-technical subjects.

Mr. M. Seaman (*British Oxygen Engineering Company*) referred to volume as related to production and industrial engineering training. Everyone was well aware, he said, of the measurements made in the past — of the great difference between the increase in productivity per annum, of the very big improvements in technical methods in America and their very much higher ratios in the weight of effort as a whole in the technical training picture. Everyone here was quite saturated in it and some of the arithmetic of the problem to which Professor Connolly had already referred had been acquired.

On a recent visit to America, however, he had found they were preoccupied with another problem. It might be merely significant of the times, but some of their intelligence people had found out that the Russians were producing twice the output of engineers, technologists, and business administrators that was being produced in the United States.

It was interesting that this had prompted the State Department to put forward a sum in the region of two million dollars to finance studies on why the Americans were so far behind the Russians. It would be interesting to consider why the British were so far behind the Americans and, therefore, so much farther behind the Russians. Perhaps some stimulus would be added by the discussion that evening to this very necessary exercise.

If the figures were to be believed, there was a ratio of 8 : 1 in the case of the United States and the United Kingdom in these classified types of administrators and engineers. In the case of Russia and the United Kingdom the ratio was apparently 16 : 1. That was the scope of the problem.

Another thing which bedevilled the matter was that the age scale was not long enough. Nobody could become a competent production engineer or professional at anything else without a training range from, say, 16 to 30 years of age. Therefore, assuming that this was the area of time involved and taking the total population, the various disciplines and streams by which these people were acquired became less significant, provided the total content was of the right volume; that was to say, not one-sixteenth of the Russian figure. It was statistically inaccurate to assume that only the intellectuals were of importance in this matter. People with kick and drive, with the addition of good training, were in fact probably very important types after 30 in the whole machinery of production, technology and so forth.

From the point of view of the industrialist, as far as he could speak of it, it seemed that there was an immense dearth of people with the right training, for both the reasons given : first, many more of them were needed; and secondly, as Professor Connolly had so strongly emphasised, at present the technical rate of change was so high that still more would be needed.

It was perfectly true to say that on the financial side every budget one examined in America had massive expenditure in this field. The root of the matter was that people in this country were not convinced of the need for such expenditure. It was an absolute fact that their late Victorian traditions still held them back and they were possibly twenty-five years behind where they need be. What was needed was a reorientation of thought.

What it came down to was that there were a tremendous number of worthwhile people who were not getting the training they could be given, and there were a tremendous number of industrialists who were convinced that they ought to have it. These two aspects must be combined.

Mr. Seaman had had actual experience himself, because he had sent some of his people to the diploma courses where they did 750 hours instead of 180 to 200 hours per annum. The results had been very well worth while. But it still came down to the fact that sufficient people did not spend sufficient time on training and were not given the opportunity that was wanted.

One might well take a leaf out of the American book. It was a matter of stimulation and education; and they were using the fact of their being behind the Russians in the present phase as a stimulus to drive and effort. Some study should be devoted to the same subject in this country. Nothing would teach the half-witted and the backward so much as the threat of the difference between the Russians and the British, for instance. If the Americans were feeling worried, the British also should avail themselves of the opportunity to achieve some improvement. He thought everyone would agree that only a relatively feeble effort was being made in this field at the moment. The next step was to strive for a strong stimulus to effort, knowing that the industrial prosperity of the country depended on it in the final issue. Out of that would come, quite apart from the arithmetic of the thing, the real effort that was so necessary.

Mr. C. R. English (*Staff Inspector for Production Engineering, Ministry of Education*) pointed out that in talking about Higher National Certificates one should not be led astray by titles. Prior to 1940, students taking Higher National Certificates in Mechanical Engineering would have studied such subjects as thermodynamics, theory of structures and mechanics of fluids, in addition to basic mathematics, materials and machines. Now, with an enormously increased number of students taking the Mechanical H.N.C., over 60% of them were taking machine tools and metrology in place of the traditional subjects. Surely this trend must be acknowledged when discussing the education of engineers concerned with production.

Furthermore, a number of colleges, increasing each year, were offering a further year of studies beyond such a Mechanical Higher National Certificate, these studies being concerned with production engineering technology and leading to the award of the Higher National Certificate in Production Engineering. To many of them, this was a good scheme, for a sound study of mechanical science preceded the specialised study of production technology.

There was one major problem needing attention at the present time. Pupils leaving secondary schools fell into two main groups — (a) those leaving at 16 or earlier, and (b) those continuing to 18. The former group was well catered for with existing National Certificate and City and Guilds courses. Of those staying until 18, a number would go on to University. There were few production engineering courses in Universities at present. The number was growing and would almost certainly continue to grow, but it was a fact that few of this highly selected group would receive a production engineering education. It was, therefore, most important to provide training in industry and education in the technical colleges for those pupils who stayed at school until 18, and did

not go to University. This group was still highly selective, having probably done well in the G.C.E. examination at 16, as a prerequisite of staying on at school until 18. It was to students such as these, together with those achieving above average success in the Ordinary National Certificate examinations, that sandwich diploma courses were so well suited. These courses, an increasing number of which were including a substantial amount of production technology, were one of the happiest developments of the post-war period.

In spite of these developments, there was still need for the 'straight' Higher National Certificate in Production Engineering. The courses mentioned earlier were all built round mathematics. Whilst there was clearly a need for good mathematicians in this field, there was also surely a place in production engineering for a less mathematical approach. One of the functions of the production engineer was man management and this did not always go with mathematical ability. Hence the need to retain a course of a more practical nature such as the existing Higher National Certificate in Production Engineering. It was not very realistic to speak of raising the level of this course substantially if one remembered the time limitations of part-time courses.

One final point: the new Notes for Guidance of Colleges running Production Engineering Courses had arrived from the printers that day. The Notes had been prepared by the Joint Committee representing the Institution and the Ministry and represented a substantial development of the scheme started in 1940. The intention was to broaden the course by endorsement studies in such subjects as personnel studies, statistical techniques, industrial cost accounting, and electronic control. Fifteen years was not a long time for a course to establish itself alongside other firmly established engineering courses. The numbers were growing — admittedly more slowly than one would hope — but in this speaker's opinion the picture was not so dismal as it had been painted.

Mr. G. M. Saul-Brown (*Chief Education Officer, de Havilland Aircraft Co. Ltd.*) speaking from the industrial standpoint, said that some firms were fully alive to the situation. In his own firm, about 2,000 apprentices were attending courses. Many of them read for the London B.Sc. engineering degree. Others followed a National Diploma course. The majority took the Higher National Certificate in Mechanical or Production Engineering, and many of them coupled the two. They took the Ordinary National Certificate in Mechanical Engineering with possibly a Production subject added. This enabled them to pass over either to the Production or Mechanical Higher National Certificate. They might reach the point where they had, with their endorsements, the dual qualification of the Institution of Mechanical Engineers and the Institution of Production Engineers.

It was felt that the point of decision came at the National Certificate stage and it was largely mathematics that would decide whether they should go purely for production or for mechanical plus production engineering.

He did not think it had been realised that the time factor was very important in industry. Many of those who took their three subjects in A.1 and A.2 felt that that strain was sufficient. Others could go beyond that and take additional strain, adding production subjects, making four or even five perhaps in each year, plus the endorsements.

That experiment was being carried out with the different types, and it was hoped shortly to find out what was coming off the line; how they fitted into industry; what could be done to extend their education in industrial management subjects. Some of them could easily take further subjects, but there was this important point: by the time they had finished their apprenticeship, some would possibly not have got their endorsements. They then became eligible for call-up and there was nothing at present to stop them. Two valuable years were lost, therefore, at that all-important stage in the pursuance of these higher subjects, though Professor Connolly was possibly privileged to have some of these people.

When they came back they would possibly pursue those subjects, and as Mr. Dance and Mr. English had said, they would make very good engineers. They might have reached a sufficiently high standard in mathematics to do all the problems that faced them as production engineers. But, after all, if firms wanted a mathematician or a scientist they could obtain one to work out these higher problems. As production was now a matter of team work, surely those people who had been trained by the Universities as scientists and mathematicians could naturally fit into the team where there was a very sound engineer who knew the floor of the shop and what was required. There were very few indeed who could absorb all the subjects that would be desirable to make an absolutely first-class, all-round engineer. That was why it was so necessary to find the right people to fit into a team and so to achieve greater productivity and do the necessary research work in production engineering.

Mr. Page (*South East London Technical College*) said he would like to put forward the point of view of the student himself. Why did he go to a technical college? Let them face it: he went to get a certificate. That was his prime motive, just as it was the prime motive in industry to make a profit.

Then he looked round to see what Certificate he should take. Normally he would take the Higher National Certificate in Mechanical Engineering because industry looked upon it with greater favour than the Higher National Certificate in Production Engineering. That situation must be faced.

The student only went to a technical college for what he could get out of it. One might search for these people, but what one had to do was to give them some incentive for which to work.

Mr. Page would venture to suggest that one or two points were being missed and that more consideration should be given to the student. He differed violently from Professor Connolly as to the content of the

syllabus. It did not follow that what was in the syllabus was actually being taught!

Then again more teachers were needed, and not only more teachers but teachers of better quality. The top level in education needed convincing in some cases that mechanical engineering was not more important than production engineering, and there should be no more advertisements in *The Times Educational Supplement* for teachers in the higher levels of production engineering at a salary a little more than that of the ordinary capstan and tool setter in a factory.

Professor Connolly, in reply, said that a syllabus was, of course, not an all-embracing description of a man's knowledge. Mr. Page was realistic: there was no altruism in this business. It was his own view that it was not the student who should be considered. One should consider what was needed in industry and endeavour to get the student to comply with the requirements.

Apart from all the arguments about figures, there was a sufficiently wide margin to make one apprehensive, even if there were no other measurements. But there were a number of other measurements besides the figures for this country and the United States. There was the fact, for instance, that for many products the American worker and the American engineer received three times the wage or salary paid in this country, though this was not true of all products, of course, Yet they could easily compete on world markets. It was largely a question of the product. Barbers could not compete on the same basis because their work consisted very nearly of a purely man-hour content. But even with wages and salaries three times as high and with no great advantage in regard to material costs (because these were on a world basis) there was still competition, severe competition, on world markets as well as internal competition with the products of this country.

There was clearly a considerable overall and general challenge in regard to productivity, and this was to some extent brought about by production engineering and not by harder work on the part of the American worker which, as everyone was aware, was not the solution to the problem.

Professor T. U. Matthew (*University of Birmingham*) welcomed the opportunity to make a contribution to the discussion after Professor Connolly's stimulating Paper. It was very timely that Mr. English should have called attention to the new note, which had just been issued by the Ministry of Education, forecasting the future trend in the development of Higher National Certificate courses.

This led him to raise one point: that this was very much a developing situation. Not only were the educational authorities — the technical colleges, the Ministry of Education and the Universities — anxious to meet the needs of industry. They were seeking to find ways of measuring the needs of the situation, and also the success achieved by the courses already provided.

Measurement of this sort was a new art or science, in which they were all amateurs. There was not enough data as yet on the basis of which firm conclusions could be drawn.

He fully endorsed Professor Connolly's point that one must be quite sure that the Higher National Certificate course in production engineering was, in fact, providing a basis for further study in such fields as automation, statistical methods, linear programming and operational research. These were all fields of great and growing importance, and if the Higher National Certificate course was not providing a basis for their study at an advanced level, it was falling short of the mark.

The formal education of the production engineer should not finish with the Higher National Certificate course. Some people might be so misled as to think they had reached the goal with their Higher National Certificate. That conception was completely wrong. These people should be encouraged to go on to study all manner of endorsement subjects in other fields — industrial administration, management, and human relations. In this way the Institution of Production Engineers would be able to count among its members men with a breadth of vision who could see the industrial productions problem as a whole, both from the economic and technical standpoints, and who would thus become realistic leaders of thought in industry in the future.

The educational process was essentially long-term and continuous in nature, but when it could be seen that it led to the development of outstanding leaders, the younger men would have an incentive to study production engineering. But the drive must come from the man as much as from industry, and it was essential to put across the idea that education was a continuous process and did not stop at the Higher National Certificate course, which was only the springboard for the next move.

Industry itself was, of course, providing many opportunities for young men to learn production engineering. The leading production engineers were actively training all the time the men immediately responisble to them. In addition to this "on the job" training, however, industry should be encouraged to give more and more support to the courses set up in all the technical colleges in good faith and to get their young men to take these courses. It would be a tragedy if, through lack of drive from the Institution and from industry, they were not supported and moulded and changed to meet the real needs of the national situation.

Mr. A. Vines (*Production Manager, Fairey Aviation Ltd.*) said it was admitted that the Americans and then the Russians had discovered that more engineers were needed. He had always been at a loss to know what a production engineer actually was — whether he was a technician or someone who handled people and got things done. They were two quite different people.

But there was an enormous gap in the lives of young men — National Service. He did not know

much about how people were trained in the Army, Air Force and Navy, but the Services would become more and more dependent in the future on engineers. If people called up to do their National Service could continue their training, men would not return to industry lazier than when they were called up. He was apprehensive about saying this, but it was true in some cases.

It seemed a wonderful opportunity for the nation to call up people with similar qualifications or interests and allow them time for engineering training. This could surely be done. All the necessary material for teaching could be called upon, including calling up people from the Universities to teach them! If that were given serious thought, it would be possible to train far more engineers than the Americans or Russians, because it would be compulsory.

Mr. W. A. Hird (*Twickenham Technical College*) said on behalf of teachers in technical colleges that they had to cover so wide a range of technological subjects that they could only go to a very shallow depth. Consequently, the depth of knowledge of a Higher National student in production engineering was apt to be limited. It might be in the interests of the Institution of Production Engineers to encourage students to obtain endorsements in technological subjects.

As to the terminology, he would prefer that " product engineer ", or the term " industrial engineering ", had also been used.

Might he suggest that Professor Connolly's students were primarily management students ? Perhaps he would give his version of the type of course they followed. He said at a meeting about six months ago that twenty-five students a year were trained in this country of whom he trained eighteen. It would be helpful to have the benefit of his experience as to how the number could be improved upon.

Professor Connolly said he could not go fully into the syllabus in the limited time available. All he could say was that he did not agree that his students were management as opposed to technical students. They were all thoroughly trained first and foremost and primarily in the technique of production engineering. Nor did he agree that a fully professional production engineer could never be a technologist. He had to handle men and money, and it was inherent in industrial engineering as understood in any part of the world that he could handle the tools — machines, men and money. That was as far as he was prepared to devote time now to the syllabus.

As to proportion in the professional course, this was a matter for discussion, but he thought he had a formula. To limit a man to machines, if that was what was meant by not going deeply into technological subjects, was not to turn out a proper production engineer but a production technician, which was an entirely different matter.

The figures quoted were a little flattering, but they were approximately of the right order of magnitude as to the total number of students who had completed graduate training in production engineering in this country, as far as could be determined when the figures were given — that was to say, of the order of twenty-five or twenty-six.

The Earl of Halsbury had done considerable research about a year ago for his Paper to the Institution,* and a trivial and quite unreasonably small number of people had recognised diplomas or degrees for full professional production engineering training. They compared unfavourably with the numbers in other countries, including countries like Switzerland.

The **Hon. Secretary** (Mr. R. Hutcheson) read part of a letter from **Mr. T. B. Worth** (*College of Technology, Birmingham*). He reminded the meeting that Mr. Worth had been the Education Officer of the Institution for five years. During that time, he did a great deal of work in getting the Higher National Certificate in Production Engineering introduced into technical colleges. In those five years the number of colleges providing such courses was increased from 25 to 52.

Mr. Worth said that the answer to the question posed in the Paper was " Yes — up to a point ". The Higher National Certificate in Production Engineering, as at present offered in the majority of colleges, was predicated primarily on producing men with a knowledge of tool engineering. This was very important, since machine tools and jigs and fixtures were right at the heart of the economy of any country enjoying a technological civilization. But it was not enough — it was only one stream and could, with endorsements, be termed two-thirds technological and one-third administrative, as far as content was concerned.

There should be developed other courses in production engineering — not to replace the present one, which should be strengthened by including more analytical work — but which could be defined as one-third technological and two-thirds administrative. Work study — particularly method study — should no longer be considered as a " reserved subject ", and deferred until all technology was covered. It should come as method study at the fourth year stage and could be studied more deeply later. Also " Statistics " should be included. In America very great regard was given to this as a subject for all engineers, and they certainly made use of it.

Perhaps the most serious criticism of the present Higher National Certificate in Production Engineering was the lack of a really good mathematical basis. But the Ministry of Education were pressing for the inclusion of more mathematics where time permits, so criticism should be tempered. Also, the Ministry's " Notes for Guidance " had been revised and many courses could be developed from the list of subjects given as suitable. Each course could have a particular " flavour ".

Most important, the Institution should give a lead

(*concluded on page* 51)

* " Some Problems of Higher Technological Education " (1954 Sir Albert Herbert Paper).

Production Engineering Research Association of Great Britain

Quarterly Newsletter to the Institution

OCTOBER, 1955

Mobile Demonstration Unit

PERA Mobile Unit has continued its country-wide tour of engineering firms by visiting firms in the Coventry, Birmingham, Bedford and Luton areas. These visits are usually received with great enthusiasm and are leading to an increased demand for details of PERA recommendations on production techniques and equipment.

Automation Research

At the second meeting of PERA Automation Committee, it was agreed that PERA would conduct an operational research in this country and abroad into many of the most important aspects of automation. These include the development and application of handling devices between operations, such as magazine, hopper and vibratory feed systems, strip and coil press-feeding devices, conveyors of all types including portable units, and equipment for loading, locating, clamping and unloading of components. Particular attention will be paid to the possibilities of automation for batch and small quantity production.

Flow turning recently demonstrated at PERA.

New Building

A new research building, which is being erected by the Association at a cost of approximately £200,000, will consist of workshops, laboratories, and offices with a total floor area of about 50,000 square feet. The foundations for the steelwork are complete and it is hoped that the erection of the steelwork will begin within the next few weeks. A special 1,000 ton impact extrusion press recently received from the U.S.A. through Conditional Aid is being placed in position before the building is completed, and will be brought into operation as soon as temporary cover and power supplies are available.

Research Programmes

Research has been initiated to determine the most effective compositions and methods of applying cutting fluids used for turning alloy steel, and to investigate the effectiveness of phosphate coatings in reducing forces in the cold extrusion of low and medium carbon steels. A recently completed reaming investigation showed that, under the conditions used, the accuracy and surface finish of reamed holes were critically affected by cutting speed and feed. Investigations of small drill performance revealed that there was an optimum feed for small drills irrespective of speed within the range of conditions employed. The first stage of an investigation into the extrusion of low-carbon steel has provided useful data on extrusion forces, and has confirmed the need for exhaustive investigation of the problems of cold extrusion. Research to establish optimum operating conditions, and the most suitable tool design for extruding steel components in a wide range of sizes and shapes, will be greatly facilitated by the installation of the 1,000 ton impact extrusion press in the new building. Draft reports on these three investigations have been circulated to the members of the PERA Technical Committees controlling the investigations and final reports will be issued shortly.

A report on methods of machine tool slideway protection has been issued to all member firms.

Monthly Bulletin

In addition to the production engineering abstracts, editorial articles on machine tool slideways and developments in press feeding and unloading have appeared in PERA Bulletin. The article on machine tool slideways refers to the PERA report recently issued and comments on the factors affecting accuracy of slideways including consideration at the machine design stage, the reduction of corrosive effects of cutting fluids, damage caused by tools and workpiece, and the use of slideway covers and scrapers. The article on press feeding and unloading briefly surveys recent progress in the use of devices such as mechanical hands, vibrating and rotating hoppers, systems for linking successive pressing operations, the removal of scrap, etc. A short bibliography gives a list of recent articles on these subjects which have previously been referred to in PERA Bulletin.

CORRESPONDENCE

From: Professor J. F. Baker, O.B.E., M.A., Sc.D., Head of the Department of Engineering, University of Cambridge.

There is a slight error in Appendix "C" of Professor Matthew's interesting Paper, "The Engineer and The Automatic Factory", published in the September issue of the Journal. The full-time post-graduate course in Theory of Structures at Cambridge is not of two years' duration, as he states, but of one session; that is, nine months, since it begins in October and ends in June.

He also omitted to mention a similar course of the same duration which should be of even greater interest to production engineers, since its subject is Control Engineering. I have just welcomed into the Department nine young men from as many well-known companies and one Electrical Lieutenant from the Royal Navy, who have assembled in this Department for the inaugural session of this course.

Like the course in Theory of Structures and Strength of Materials, which has been running in the Department for the past four years, the Control Engineering course is designed for engineers who have spent some time in industry, and it is gratifying to find that all the young men assembled today are being supported by their respective firms. Since some of the students are mechanical and electrical engineers, while control engineering is almost equally concerned with electrical, mechanical and chemical engineering, the first term will be spent in revising the relevant parts of electrical, mechanical and chemical engineering, while in the Lent and Easter terms the more advanced aspects of control engineering will be studied, including the latest developments.

Formal lectures will be provided, but a great deal of the available time will be given to laboratory experiments and to carefully directed reading. The students will be able to attend courses of lectures in allied fields of engineering and it is the object of the courses to be educative rather than narrowly specialised.

From: Dr. T. U. Matthew, formerly Lucas Professor of Engineering Production, University of Birmingham.

Professor Baker's letter reinforces two of the points which I endeavoured to make in my Margate Paper. Firstly, there have been a number of specialist post graduate courses developed at British Universities during the past few years, many of which are of potential value in the advanced education of the production engineer. It is my view that more use should be made of these courses by industrial companies, than has been the case in the past.

Secondly, the new courses in the field of Control Engineering should be of special interest to production engineers, as increasing attention is being given to new means for mechanising traditional production methods.

Professor Baker's letter underlines the importance, from the point of view of the Institution, of my suggestion that some more positive link should be developed between progressive engineering schools, such as Professor Baker's School at Cambridge, and the Council of the Institution, to the mutual advantage of both.

FULBRIGHT TRAVEL GRANTS

THE United States Educational Commission in the United Kingdom announces that, under the provisions of the Fulbright Programme, travel grants are available to citizens of the United Kingdom and Colonies to go to America for an academic or educational purpose, such as study, research, lecturing or the pursuance of other educational activities. All awards are competitive. Recommendations are made by the Commission, but the final decisions rest with the Board of Foreign Scholarships in Washington.

The basic criteria for the award of a travel grant are as follows:—

(*a*) Applicants must hold a good University degree or recognised professional qualification prior to actual departure.

(*b*) Applicants must possess a guarantee of financial support in dollars for the proposed period of the visit to America.

(*c*) All applicants must be citizens of the United Kingdom or Colonies, and are expected to return to reside permanently in their home countries.

(*d*) *Graduate students* must show proof of admission to an American institution of higher learning for a minimum period of nine months. In the case of medical internships, the hospital to which the applicant hopes to go must be acceptable to his registration body in the United Kingdom.
Candidates should be free of National Service obligations.
Grants to graduate students are valid for a period up to three years, but they are subject to annual renewal over this period.

(*e*) *Professors, lecturers and senior research workers* must intend to spend at least three months in the United States (exclusive of trans-Atlantic travel time), of which about two-thirds should be spent at one university or recognised research institution. Proof of affiliation is necessary. Grants cannot be given for attendance at conferences alone. Grants may be extended up to a period of two years, subject to satisfactory appointments and continued dollar support.

(*f*) Four years must elapse from the date of return from America before a second application may be made for a Fulbright travel grant.

Travel grants are available for travel to America between 1st June, 1956, and 1st April, 1957, for those in the lecturer/research scholar category. Those in the graduate student category are expected to go to America for the academic year beginning in September. All travel grants cover the cost of direct travel between a candidate's home in the United Kingdom or Colonies and the destination in America. The Commission arranges bookings for successful applicants.

No allowances are made for dependents' travel.

Since the funds of the Commission are in non-convertible sterling, it is not possible to offer grants for maintenance, tuition or incidental expenses within the United States.

Those receiving Fulbright travel grants are expected to travel on a special type of visa. If another type of visa has already been obtained, transfer is necessary at the time the award is confirmed.

There are two closing dates in this competition dependent on the departure date. They are:—

15*th March*, 1956, for those travelling between 1st June and 31st July, 1956.

1*st June*, 1956, for those travelling after 1st August, 1956.

Those wishing to apply are first asked to fill up a record card. *This in itself does not constitute an application.* Full-length application forms are sent only when candidates indicate that their plans are complete, which must be before the appropriate closing date. Full-length applications should be submitted via the Head of the candidate's College or University or employing body.

NOTE.—No applications can be considered after the closing dates.

Applications should be made to: United States Educational Commission in the United Kingdom, 55, Upper Brook Street, London, W.1.

Whitworth Foundation Awards, 1956

It was announced by the Ministry of Education, earlier in the year, that in order to meet changed conditions it had been decided to increase the number of Whitworth Senior Scholarships from two to three, to raise their value from £325 to £500 per annum, and to discontinue the award of ordinary Whitworth Scholarships.

Applications are now invited from candidates for the first awards to be offered under the new arrangements. These awards, now known as Whitworth Fellowships, will be available to holders of engineering degrees, or of Higher National Diplomas or Certificates in engineering with at least two distinctions, who have had at least two years' practical engineering experience. The Fellowships may be used to follow, over a period of at least two years, a course of further training in industry or post-graduate study or research in an approved establishment.

Full particulars of the conditions of entry and method of application may be obtained from the Ministry of Education (F.E.I(D)), Curzon Street, London, W.1.

Fourth Halifax Graduate Weekend School

The Halifax Section held their Fourth Annual Weekend School at the Craiglands Hotel, Ilkley, on 10th and 11th September, 1955. Due to difficulties in arranging central meeting places for the organisers, last year's experiment of holding the school on a Yorkshire Regional Graduate basis was not repeated, although members from the Region attended.

The theme of the School was "Management"—this subject was considered to be a logical development of the themes in previous years.

The School was once again honoured by the presence of the Chairman of Council, Mr. G. R. Pryor, and on Sunday, the Chairman of the Halifax Section, Mr. F. J. Everest, was present. Under the chairmanship of the Halifax Graduate Section Chairman, Mr. M. W. Alderdice, the School, which had an attendance of 28, commenced at 2 p.m. on the Saturday afternoon.

The Legal Aspects of Management

The first lecturer was Mr. J. Taylor, past Halifax Graduate Section Chairman, who spoke on the broader aspects of law in relation to the engineering manager. This address was couched in terms suitable for the engineering layman, and several little-known points of law were brought to light, both in the lecture and in the subsequent lively discussion.

Administrative Control as a Management Function

The second speaker was Mr. D. Fraser, Senior Consulting Engineer in charge of the training school of Urwick, Orr & Partners. He stressed the need for administrative control, and then proceeded to analyse the essential factors in building up control, briefly sketching in methods of application.

Mr. Fraser covered the ground completely and competently, and answered the subsequent questions so thoroughly that all members must have obtained a very clear mental picture of this subject.

The Manager and Human Relations

This was an informal discussion on Saturday evening, and was opened by Mr. G. R. Pryor. He stressed the need for accuracy of statement in debate, both verbal and written, and illustrated these points by showing how statements taken out of their context can be very misleading. He also demonstrated the stratagems which are sometimes used for dishonest purposes, either consciously or unconsciously, in debate. The discussion which followed made the audience conscious of how they could all sometimes fall victims to these practices.

Test Case

A test case was used on Sunday morning as a means of putting into practice the points raised during the lectures. The School split up into small groups to tackle the problem and the results showed how members had benefited from the lectures.

After lunch, Mr. J. Hepper very ably and lucidly summed up the work of the School.

Education Discussion Group—London Centre

On 12th November, 1955, the Group celebrated its third year of existence by a combined visit to Kingston Technical College and to the National Physical Laboratory.

Of particular interest at Kingston was the very comprehensive welding shop which is equipped with large commercial machines for resistance, spot and projection welding. This college also has under construction a supersonic wind tunnel for the Aerodynamics Laboratory.

At the N.P.L. in the afternoon, the Group visited the Metrology Division and were permitted to inspect the large comparator used for checking the Imperial Standard Yard.

A visit was also made to the new workshop of the Aerodynamics Division to see the new equipment installed for producing models of airfoil sections to be used in the supersonic wind tunnel. High speed flight developments have necessitated higher standards of accuracy in the construction of aerodynamic models which must now be made of metal to a tolerance of 0.005″. The models are machined by means of a series of flat-faced cuts which are planes tangential to the curves making up the airfoil section. Machining is by milling on a high-class jig boring machine and the final finish is imparted by surfacing grinding which also produces a series of tangential flat faces on the model.

By a comprehensive layout of angles of tilt and the positions of the flats, the airfoil section produced is remarkably smooth and is well within the fine tolerances demanded.

Construction of these models is complicated further by the need to fit bushes at many positions in the airfoil surface. These bushes are connected to tubes which are embedded in the section; alternatively, the tubes are in the form of drilled galleries. The connections to the bush bores terminate outside the model in a multiplicity of small diameter capillary tubes.

The Education Discussion Group is a body formed to study teaching methods and has, so far, approximately fifty members on its mailing list. These members are all teachers engaged in full-time positions in technical colleges in the Southern Region. The Group welcomes any Institution members who are interested in technical education and its techniques and they are particularly interested in hearing the views of education and personnel officers who are employed in industry. Further details can be obtained from the Group Hon. Secretary, Mr. C. T. Bower, 25 Emlyn Road, London, W.12, or from the Chairman, Mr. W. Hird, 35 Kneller Road, Twickenham, Middx.

news of members

Mr. G. R. Blakely, Member, has been appointed to the Board of Directors as Works Director of G. A. Harvey & Co. (London) Ltd. Mr. Blakely is a member of Council and is Vice-Chairman of the London Section.

Mr. E. Percy Edwards, Member, who resigned from The Lapointe Machine Tool Co. Ltd., has joined The Catmur Machine Tool Corporation Limited, as Birmingham area Sales Manager. He will continue to operate from White House, 111 New Street, Birmingham, 2.

Mr. William Fenton, Member, has resigned his position with The Yorkshire Copper Works Limited, Leeds, and has taken up an appointment with The Northern Aluminium Co. Ltd., Rogerstone, Newport, Mon.

Mr. J. C. Routledge, Member, Works Director of Gimson & Co. (Leicester) Ltd., has been appointed Director and General Manager of that Company.

Mr. G. F. Shrigley, Member, has relinquished his present position as General Manager of British Light Steel Pressings Limited, a Rootes Group Company, and has been appointed Director of Production, Rootes Group Manufacturing Division, and will serve on the Boards of the various Manufacturing Companies.

Mr. R. J. Broomer, Associate Member, who relinquished his position with Joseph Sankey & Sons Limited, Bilston, is now Development Engineer with F. J. Ballard & Co. Ltd., Tipton, Staffs.

Mr. H. Burrows, Associate Member, has left the Stafford County Technical College, and is now Principal of the Verdin Technical College and School of Art, Northwich, Cheshire.

Mr. B. W. Charman, Associate Member, has relinquished his position as Senior Design Engineer with Cyril Adams (Special Project) Ltd., and has taken up an appointment as Chief Draughtsman with Messrs. Rhoden Partners Limited, London.

Mr. W. R. Childs, Associate Member, has relinquished his position with the Parkinson & Cowan Group, and has taken up an appointment with Raleigh Industries Limited, Lenton, Nottingham.

Mr. D. Gemmell, Associate Member, has recently been appointed General Manager of Metind Limited, Birkenhead.

Mr. H. P. Halfter, Associate Member, the Corresponding Member for West Africa, has been promoted within Her Majesty's Colonial Service to the rank of Senior Electrical Engineer and holds the appointment of Head of Electrical Engineering Department, Gold Coast Railways and Harbour Authority.

Mr. D. A. Jones, Associate Member, has relinquished his appointment with Messrs. Lucas Rotax Limited, Canada, and has taken up an appointment as Consultant by Messrs. Fairchild Camera and Instrument Corporation, Long Island, New York.

Major M. H. Moore, Associate Member, has relinquished his appointment with the Israeli Government earlier this year and has taken up an appointment with Messrs. Marks and Spencer, Building and Equipment Department.

Mr. R. Rees, Associate Member, has taken up an appointment as Production Controller at the British Light Steel Pressings Limited, Acton, W.3.

Mr. T. A. C. Williams, Associate Member, has now been transferred to the East Midlands Division, Area 7, of the National Coal Board.

Mr. F. G. Ethelston, Graduate, has taken up an appointment as a Metallurgist in the Metallurgy Laboratory, responsible for Heat Treatment Development, at C.A.V. Limited, Acton.

Mr. J. Scarf, Graduate, has now left R. W. Crabtrees & Sons Limited, Leeds, and has taken up a position as Design Engineer with The Forgrove Machinery Co. Ltd., Leeds.

Mr. Eric L. J. Thorne, Graduate, has been promoted to the new post of Assistant Works Manager from that of Production & Planning Engineer at his present Company, Cylinder Components Limited, Kings Norton, Birmingham.

NOTICE OF ANNUAL GENERAL MEETING

NOTICE is hereby given that the Annual General Meeting of the Institution will be held at 10, Chesterfield Street, London, W.1, on Thursday, 26th January, 1956, at 2 p.m.

Agenda

1. Notice convening Meeting.
2. Minutes of the Annual General Meeting held on 27th January, 1955.
3. Report on Election of Members to Council.[1]
4. Annual Report of Council.[2]
5. Presentation of Statement on Income and Expenditure, Balance Sheet and Auditors' Report.[3]
6. Election of Auditors, 1955/56.
7. Election of Solicitors, 1955/56.
8. Votes of thanks.

By Order of the Council.

W. F. S. WOODFORD, *Secretary.*

1. See page 53.
2. See page 53.
3. See page 63.

" Does The Higher National Certificate in Production Engineering Meet the Need of Industry?"

DISCUSSION—continued from page 45.

in this matter, and Mr. Worth did not think they were doing so at the moment. So long as the Associate Membership examination remained static, so would development be retarded. He was very proud of the fact that during his term with the Institution, major developments took place in the educational field, but it was never his intention to let things stay there. The Associate Membership Examination was now five years old and should be critically assessed and revised to reflect current thought. The production engineer of the future would have to be a scientist as well as an engineer.

Mr. Worth hoped, he said, to make his report on " American Methods of Education and Training in Industrial Engineering and Management " before long, and that might reflect some of the ways to which this country might modify courses. (*Note: This Report is now available.*)

Finally, he said, the Institution of Production Engineers must do everything possible to achieve full professional regard and to dispel the idea that production engineering was only concerned with machine tools, metrology and jig and tool design. They must not misunderstand him. These were most important and should continue in full strength. But they were not the only subjects. Also, no examination scheme would produce good men unless it attracted good material.

MINUTES OF THE ANNUAL GENERAL MEETING

held on Thursday, 27th January, 1955

THE thirty-third Annual General Meeting of the Institution was held on Thursday, 27th January, 1955, at 4 p.m. at the Headquarters of the Institution, 10, Chesterfield Street, London, W.1. The President, Sir Walter Puckey, was in the Chair.

Notice convening Meeting

The Secretary (Mr. W. F. S. Woodford) read the notice convening the Meeting.

Minutes

The Minutes of the previous Annual General Meeting held on 28th January, 1954, were taken as read, and confirmed on the motion of Mr. E. F. Gilberthorpe, seconded by Mr. B. E. Stokes.

Elections of Members to Council

The Report on the Election of Members to Council was received on the motion of Mr. R. E. Mills, seconded by Mr. B. G. L. Jackman.

Annual Report of Council

Mr. G. R. Pryor, in moving the adoption of the Annual Report, said that the New Building Fund now totalled £16,500 and a few small donations were still being received. The Finance and General Purposes Committee's forecast at the end of the current financial year was that the overdraft would not exceed £4,000. The present year's finances were going very much according to budget, and there was the suggestion according to the trend that at the end of the year the surplus was likely to be somewhere around £2,000.

Membership continued to increase. Most members of Council were present when a further 78 members were elected that day, and it would seem that the tightening up of the membership regulations had not in any way stopped the flow of new members to the Institution.

Mr. Gould seconded the motion, and the Annual Report was adopted.

Statement of Income and Expenditure, Balance Sheet and Auditors' Report

On the motion of Mr. G. R. Pryor, seconded by Mr. F. T. Nurrish, M.B.E., the accounts were adopted unanimously.

Election of Auditors, 1954/55

On the motion of Mr. S. A. J. Parsons, seconded by Mr. A. G. Clark, Messrs. Gibson, Appleby & Co., Chartered Accountants, were re-elected Auditors to the Institution and thanked for their services.

Election of Solicitors, 1954/55

On the motion of Mr. E. P. Edwards, seconded by Mr. M. C. Timbury, Messrs. Syrett & Sons, were re-elected Solicitors to the Institution and thanked for their services.

Votes of Thanks

The President said that he had the extremely comprehensive task of thanking Mr. Harold Burke, Mr. G. R. Pryor, and all Officers of the Institution, but he did not feel that a "composite" vote of thanks was sufficiently personal.

The Annual General Meeting dealt with the previous year during which period Mr. Burke was the Chairman of Council. There was a great deal for which Council had to thank Mr. Burke. He had put in a great deal of time which was of the utmost value to the Institution, and as Chairman of Council, he had conducted the business of the Council in an admirable manner.

It was also right to speak in a similar vein of the present Chairman of Council, Mr. Pryor. One of the most important things which any man could do in life was to make sure that his successor followed in the tradition which he had tried to set up. In the case of Mr. Pryor, it would be unanimously agreed that he was a Chairman who was not only following, but standing well ahead of, the tradition. He had a delightful personality, he was a man who got things done in a very efficient manner and a man who, although he had not always been in the best of health, had given the Institution of his best. The Council were proud to have him as Chairman.

It was with great pleasure that the President moved a hearty vote of thanks to Mr. Burke, Mr. Pryor and to all Officers of the Institution. The vote of thanks was carried by acclamation.

Mr. G. R. Pryor, in response, thanked the President for his kind remarks and members of Council for the way in which they had received them. Unfortunately Mr. Burke was indisposed otherwise he would have been present. He would be delighted when the sentiments which had been expressed were conveyed to him.

The Institution was indeed very fortunate in its permanent staff. Although their services were acknowledged he desired to take the opportunity of assuring them how much the Council and members appreciated that which they were doing, and the interest as well as the loyalty they showed. He had much pleasure in proposing a hearty vote of thanks to the permanent staff of the Institution. The vote of thanks was carried by acclamation.

On the motion of Mr. H. G. Gregory, a hearty vote of thanks to the President was carried by acclamation, and the General Meeting then terminated.

REPORT ON ELECTION OF MEMBERS TO COUNCIL, 1955/1956

In accordance with Article of Association No. 34, there were nine vacancies for elected Members of Council (eight Members and one Associate Member).

For the nine vacancies for elected Members fourteen nominations were received. As a result of the ballot conducted in accordance with Article of Association No. 43, the following were elected :

Mr. G. R. Blakely	Mr. E. Levesley
Mr. A. E. Clifford	Mr. R. N. Marland
Mr. H. H. Dawson	Mr. H. Spencer Smith
Mr. A. F. Kelley	Mr. H. Tomlinson

For the vacancy for the elected Associate Member four nominations were received. The Associate Member elected was :

Mr. Robt. Hutcheson

Ballot papers were circulated to 5,250 Corporate Members in the United Kingdom. Details of the voting issued by the Institution's Auditors are as follows :

Eligible Papers included in the ballot		1433
Rejected :		
Incorrect number of votes recorded	31	
Papers not marked in ink	15	
Spoiled Papers	3	
Envelopes unsealed	7	
Received from G.P.O. as unable to deliver	1	
Papers signed	1	
Insufficiently stamped—returned to G.P.O.	7	
Papers received after closing date	22	87
		1520

The full list of Council Members for the current year is published in the Journal.

REPORT OF COUNCIL

1st July, 1954 to 30th June, 1955

TO BE PRESENTED BY THE CHAIRMAN OF COUNCIL AT THE ANNUAL GENERAL MEETING
Thursday, 26th JANUARY, 1956.

THE Annual General Meeting is the one occasion each year when we can draw together the threads of all our activities and survey the past year's work as a whole. Since all our many activities are reported upon in the Institution's Journal, when they occur, the Annual Report can obviously contain little that might be termed "news", but is chiefly an historic document. Nevertheless, I believe it is very valuable to make this annual review; to draw inspiration from our successes and guidance from our failures, in shaping our future policy.

Notable Changes

On the whole, the year under review was one of consolidation. As I mentioned to you in my Report last year, the year 1953/54 saw several notable changes in the Institution's way of life. Your Council, through its Committees and the executive staff, have concentrated mainly on gathering our resources for a fresh move forward — not, I would hasten to add, that we stood still during last year. On the contrary, several new projects were instituted and we finished the year in a blaze of glory at our Conference at Margate, to which I shall refer again later.

Your Council held four meetings during the year and I should like to take this opportunity of expressing my appreciation of the support and encouragement which all members of my Council have extended to me, as their Chairman for the year. I am happy to report that our Council meetings are conducted in an atmosphere of friendly co-operation. A number of important points of Institution policy have been discussed at our meetings but although divergent views have been expressed, we have succeeded either in reaching agreement or in carrying our differences forward to subsequent meetings without acrimony.

The bulk of the Council's business time is devoted to considering and adjudicating upon the reports and recommendations of the various Standing Committees and Regions. In addition to this work, several important debates on Institution policy have been held but as all these have been reported in the Journal, I will simply refer here very briefly to the main points.

The Production Exhibition and Conference

The Council held a review of the Production Exhibition and Conference which we held at Olympia from 7th - 14th July, 1954. It was the unanimous view that the Council had been well advised to sponsor this Exhibition and to promote the Conference and it was agreed that the Institution should accept the invitation of the Exhibition Organisers to sponsor the next Production Exhibition which is being held at Olympia in May, 1956. Again, concurrently with this Exhibition, your Council will promote a Conference and a Special Committee under the Chairmanship of Sir Walter Puckey has been set up to deal with this. The fact that Sir Walter, our immediate Past-President, has undertaken this task is sufficient guarantee that it will be pressed to a successful conclusion.

The British Productivity Council published a report of a team which visited the United States of America to study Industrial Engineering. This report was discussed at length by your Council.

The membership policy, as exemplified in the phrase "Broadening the Base" has promoted considerable discussion. As the implementation of this policy falls very much upon the Education and Membership Committees, I will refer to this again when I report on their activities later.

Another notable debate was on the subject of "The Place of the Graduate Member in the Institution" A number of Graduate members from various parts of the country were invited to the Council meeting for this occasion and they made some most valuable contributions to the discussions.

Official Opening of 10, Chesterfield Street, London, W.1.

The Institution's new Headquarters, which we occupied in May, 1954, were declared officially open on Thursday, 28th October, 1954. The delay between taking possession and officially declaring the building open was occasioned by the fact that the building contractors had not completed their work when we moved in. To ensure that every section of the Institution's membership was represented, the President invited the officers of all the Institution's local Sections to attend the ceremony. The Presidents of our kindred Institutions were also invited, together with the heads of many of the companies who had made generous donations to the New Building Fund. Many of the Institution's friends from among the technical and national press were also present. The Official Opening was conducted by Sir Walter Puckey, who presided in the absence of Sir Leonard Lord, who was unable to attend.

Margate Conference

Far and away the most important event of the year was the Conference on "The Automatic Factory — What Does it Mean?" which was held at Margate in June, 1955. A total of 1,103 members and visitors attended this Conference, many from distant parts of the World. When the applications to attend came pouring in to our Head Office, the Organising Committee had some anxious moments as to whether or not such a large number would be manageable or whether a Conference of this size would not fail in its impact because of division of interest. However, thanks to first-class team work under the leadership of Sir Walter Puckey, the President, Gen. K. C. Appleyard, Chairman of the Conference Organising Committee and Mr. A. F. Kelley, Chairman of the Programme Committee, which achieved the closest possible collaboration between the members of the Committee, the Chairmen of the Sessions, the speakers and the executive staff, the Conference ran smoothly throughout. We maintained our time-table to the minute and, what was really most gratifying, from the very start — in spite of the enormous number of people attending — a congenial conference atmosphere was engendered.

The subject of the Conference made a tremendous public impact. Automation has been growing in importance and news value slowly over the past 15 years. The Institution's Conference succeeded in focussing attention and the publicity which followed has ensured that a consciousness of the tremendous problems involved has become evident in all walks of life. Since then a Special Committee has been set up under the Chairmanship of Mr. A. F. Kelley, to study further the implications of automation.

The Conference had been publicised as a hard-working one, with the minimum amount of time to be devoted to sociable activities. It was notable that every session, both Plenary and Discussion Groups, was packed to capacity and considerable discipline had to be exercised by the Chairmen to ensure that the discussions were brought to an end at the proper time.

This Conference has set the Institution a very high standard of attainment for the future and I extend our congratulations and thanks to all those members who contributed to its success.

Visitors

There has been a steady stream of visitors to our Headquarters during the year. Members of the

Institution are always assured of a welcome at Headquarters and I hope that many will take the opportunity, when visiting London, to call at Number 10, Chesterfield Street.

It is gratifying that we have had so many visitors from outside the United Kingdom. Almost every section of the membership outside the United Kingdom has been represented by our visitors during the year and the personal contacts and friendships which are thus made are invaluable in maintaining relations with our members all over the world.

Standing Committees

The Institution's constitution is so arranged that the greater part of its routine business is under the control of the various Standing Committees, who are elected by the Council. The Standing Committees are kept very busy and the following is a report of their principal activities:

Finance and General Purposes Committee

Your Finance and General Purposes Committee might perhaps be regarded as the Institution's "Cabinet", as the Chairman of each of the other Standing Committees is automatically a member of it. In this way, your Finance and General Purposes Committee is able to keep a constant watch over the whole field of our activities and to see that the Council is kept fully informed of our financial trends.

The accounts for the year have been circulated with this report and I am sure that you have all studied them very closely. Their adoption is a subject of another item on the agenda and you will be able then to ask questions or to make comments, but I should like to take this opportunity of referring to some points of interest.

The full accounts have been published on pages 63 to 65 in the January 1956 Journal and you have all had an opportunity of studying them. May I direct your attention for a few moments to the Income and Expenditure account?

Dealing with expenditure first, you will notice that our establishment charges are rather higher than in the previous year. This is because in 1954 we were the greater part of the time in our old premises in Portman Square. The current figures show the increased costs of 10, Chesterfield Street for the whole year.

Administration expenses show an increase of just over £200 for the year. You will notice that the biggest increase is under the heading of Printing and Stationery. This was occasioned by the fact that we printed an extra large amount of our various membership and other leaflets for distribution at the Margate Conference.

Salaries show a substantial increase over the previous year. Here again, in 1954 we were without the services of an Education Officer for the greater part of the year. The current accounts include the Education Officer's salary for the full year and, in addition, adjustments to other salaries have been made, to which I will refer later.

Section expenses show a modest decline from the previous year, in spite of the increased Section activity. Under the new Regional system funds are allocated to each region and the Regions, in turn, allocate their funds to the local Sections. We are indeed grateful to all our Regional and Section officers for their co-operation in keeping close control over our expenditure.

Expenditure on the Journal shows a substantial increase over last year which is due to its greatly increased size. On the income side, you will see that the Journal receipts have correspondingly increased. We are making some adjustments in our method of costing the Journal during the current year.

Other items of our expenditure are self-explanatory, except that you may wonder why we have set up a Renovations Reserve as the last item. Your Council have decided to set aside a small sum each year to build up a reserve for the maintenance of our Headquarters at 10, Chesterfield Street. Major redecorations are very expensive nowadays and I think you will agree it is wiser to spread the cost over a number of years.

Turning now to our income, you will notice that revenue from Renewals and Arrears of Subscriptions shows an increase over last year, which reflects our increasing membership. Transfer fees and New Subscriptions together were rather lower than last year, which reflects a slowing down of our membership intake as a result of more stringent regulations. Overseas Subscriptions are about the same.

We have included a new item in the accounts this year, namely, Registration and Miscellaneous Fees. This arises from our new regulations and, in many cases, takes the place of the former entrance fee. Thus, in comparing with last year, the two figures "Entrance Fees" and "Registration and Miscellaneous Fees" should be added together and they show an increase.

Recovery of Income Tax on Covenanted Subscriptions requires an explanation. The amount of £5,546 shown in the accounts represents the recovery of two years' income tax on our covenanted subscriptions. At the end of last year, an amount was outstanding but as there was no guarantee that the Inland Revenue would make this refund, it was not taken into account. This amount was, in fact, recovered during the year and we have also since received a refund from the Inland Revenue in respect of the Income Tax on covenanted subscriptions for the year covered by the accounts. We are therefore able to include both these sums this year.

Conferences and similar functions have now become a regular part of the Institution's life. In the past we have generally subsidised these activities but your Council now feels that the time has come when activities of this kind should pay their way wherever possible. The small surplus shown in the accounts was earned mainly by the Margate Conference.

The net effect of our working for the year is to show an excess of income over expenditure of £7,072. This figure is naturally inflated by the sum of £5,546 received from the Inland Revenue. Thus, our effective excess of income over expenditure is of the order of £1,500. There is a separate analysis of this figure which I will deal with later on.

We have made one or two adjustments in the Appropriation Account to which I should like to draw your attention. When the Institution ran a pilot scheme to test whether or not the Inland Revenue would accept the payment of membership subscriptions under deeds of covenant, the revenue returned for that year was £464. Your Council agreed in principle at that time that any refunds from the Inland Revenue under this heading should not be regarded as ordinary revenue, but should be transferred to a special reserve fund and accordingly this sum of £464 was reserved. Your Council feel, however, that there is not much point in setting up a reserve unless there is a corresponding fund of investments against that reserve. As we are still working to a modest overdraft, your Council felt that there was no point in investing a sum of money in gilt-edged securities, which could only be done by increasing the amount of our overdraft on which the charges would be higher than the interest earned on the investment. Accordingly, your Council's policy for the time being is to add these refunds of income tax to the accrued balance of the income and expenditure account until such time as we have a surplus of cash which we can use to make appropriate investments.

Turning to our assets, the right-hand side: the freehold premises still stand at their purchase price. I am very glad to report that during the year many small contributions to the Building Fund were received. These have been applied to the alterations to and equipment of our new Headquarters, which have cost us altogether in the region of £15,000. The splendid response to our Building Fund Appeal has enabled us to reduce this figure in the balance sheet to the very modest sum of £2,813. Thus, the total cost of our freehold premises and alterations amount to the balance sheet figure of £37,813. This is a solid security which, in the present day market, I am sure is worth considerably more than this sum. Our furniture, fittings and plant are written off on a ten-year basis. They stand at the moment at £4,853. Again, this is a very modest valuation of this asset.

Our Fund investments remain unchanged and they are listed on the annexed statement.

Our current assets show an increase over last year and they slightly exceed our current liabilities on the other side. Although we have an excess of current assets over current liabilities, it is only the sum of £1,758. Our accumulated funds of £26,100 remain the same. The special reserve has now been added to the total of the income and expenditure account, as I have just mentioned.

Renovations Reserve is a new item upon which I commented when dealing with the income and expenditure account. The amount which was reserved last year for the Hazleton Memorial Library Catalogue has been absorbed and the Catalogue is now available to members.

If you will now turn to the analysis which is published separately at the end of these accounts, I think you will be able to get a clearer picture of our position. We have summarised the income and expenditure account so that you can see the relative positions between the United Kingdom and the Sections outside the United Kingdom. You will recall I mentioned that if we made an adjustment for the sum of £5,546 recovery of income tax on subscriptions, our net excess of income over expenditure over the year amounts to £1,526. The summary shows that Sections outside the United Kingdom altogether aggregated an excess of income over expenditure of £2,184. Thus, there was a net deficit on the home account for the year amounting to £658. It is understandable that a deficit should be shown in this way since no allocation is made to overseas Sections on account of the central administration of the Institution, including the cost of producing and distributing the Journal.

Nevertheless, your Council is not happy at the moment about the United Kingdom income and expenditure. Inflation is rapidly catching up with the Institution. Our costs are rising rapidly every year although the rate of our membership subscription remains unchanged. Your Finance and General Purposes Committee is giving the most serious and careful attention to this problem.

The analysis of assets and liabilities shows how the various items under this heading are distributed between the United Kingdom and Sections outside the United Kingdom. Whilst in our published balance sheet we show a net overdraft of £615, you will see from this analysis an overdraft on the United Kingdom account for £4,804. This overdraft only exists for a few weeks of the year and generally builds up during June, just before our annual subscriptions fall due. Against this, we have cash investments outside the United Kingdom amounting to more than £4,000. Sections outside the United Kingdom do help us at Headquarters by remitting cash to us direct during the year. The amount of cash which was actually received from our Sections outside the United Kingdom during the year under review amounted to £2,350.

Closer Co-operation with PERA

It has been a source of great personal disappointment to me that since our Research Department was closed down and the Production Engineering Research Association established as a separate entity, the two bodies have seemed to drift apart. It is manifestly desirable that there should be a very close relationship between PERA and the Institution of Production Engineers and, with this in mind, it was arranged for a group of representatives of both organisations to meet during the year and to discuss ways and means of establishing closer relations between us. I am happy to say that their proposals have been adopted by both Councils and will be given effect during the current year. I will not comment on the details since this will be a subject for next year's report, except to say that I am quite sure that the proposals will bring benefits to both bodies.

Head Office Administration

The Head Office of the Institution has become increasingly handicapped in efficiently discharging its functions by the extreme difficulty of maintaining a

full staff. As a result of the growth of industry in outer London, many people who might have earned their living in Central London now find that they can secure well paid appointments near at home and thus save themselves the tedium of long journeys on crowded transport night and morning. As a consequence a good deal of temporary staff has to be engaged, which is not only inefficient, but is very expensive.

To advise us on this serious problem your Finance and General Purposes Committee called in the services of a leading firm of Consultants. It happened that the Directors of this particular firm are members of this Institution and they very kindly agreed to carry out a survey for us at a purely nominal fee, and we are very grateful to them. As a result of this survey we have been able to eliminate some of the tedious lower grade clerical operations in the office and some of the other operations have been rearranged, not only with a view to improving the general efficiency of our Headquarters, but to strengthen the Secretary's hand in building up his staff.

The problems are not yet all solved. There seems to be a great restlessness in the Capital and junior staff appear to jump in and out of jobs as a matter of whim. It is thus extremely difficult to maintain continuity and a good deal of hard work is put in to training young members of the staff who then leave and get appointments elsewhere.

Part, but not all of the difficulty, is the level of wages which our staff is paid at Headquarters. Clearly we have an obligation to see that our staff is adequately remunerated but, on the other hand, the Institution's financial background is such that we are unable to be fully competitive with the high level of salaries which is set by many of the very large commercial undertakings in the West End of London. Your Committee accept in principle that some adjustments must be made and the Secretary has been given some discretionary powers in this direction, to operate during the current year. I hope that next year we shall be able to report some improvement in the situation.

Your Finance and General Purposes Committee have had many other matters under review during the year, but as these mainly come through the other Standing Committees they will be dealt with in the appropriate place.

Editorial and Papers Committees

Although these Committees are quite separate in their constitution, their work is so closely linked that it is appropriate that we should consider them together. Throughout the year both Committees have vigorously pursued their joint aims of making the Institution's Journal the most outstanding in its field.

It is a matter of much gratification to the Committees that support from advertisers has not only been maintained but increased during the year, which is an indication of the level of importance which is attached to the Journal. The additional revenue which has accrued from this has been ploughed-back in to the Journal to improve the editorial content and general presentation. The average number of editorial pages each month during the past year was 65 as compared with 55 during the previous year, which shows a notable increase in the amount of information we are able to convey to members through the medium of the Journal.

In the past it has been our practice when considering the finances of the Journal to set the revenue against the actual cost of production and distribution and no account has been taken of the Journal's share of the overhead charges accruing from the Head Office general administration. On this basis, our Journal paid its way on the year's working. It was agreed, however, between the Editorial Committee and the Finance and General Purposes Committee, that it was not sound economics to ignore the indirect cost of the Journal in terms of Head Office overhead charges. On a reasonable computation it was felt that a fair charge on the Journal for overheads would be in the region of £2,000 a year, and the Editorial Committee undertook to explore the possibilities of increasing the Journal's revenue by this amount. Negotiations took place with the advertising agents, which resulted in the drawing up of a new contract which came into effect on the 1st January, 1955. The old contract had been in force since 1931 when the Institution's Journal was quite an insignificant publication and the Editorial Committee felt, quite justifiably in my view, that the greatly enhanced status and circulation of our Journal merited the Institution seeking better terms with the advertising agents. The new contract has achieved this purpose and will result in the Journal revenue being increased by approximately £2,000 a year. Some benefit from this new arrangement has already been shown in our current accounts, to which I have just referred. The increase over the full year will be shown for the first time in our next published accounts.

Apart from the advertising contract, the Editorial Committee have had continually under review the production and distribution costs of the Journal and I think it is probable that next year we shall be able to report further savings.

The Papers Committee are making every effort to obtain more papers of the high standard required for publication in the Journal. The Committee still believe that there is considerable scope for improvement in the local Sections and they do feel that our Section Committees do not take sufficient advantage of local talent. It has always been our policy in the past to publish only papers which have been presented to a meeting of the Institution but, as a means of securing an additional supply of papers, the Papers Committee have tried to encourage members and non-members to submit papers for consideration for publication whether they are eventually intended for presentation at a meeting or not. The Committee are convinced that there is a great deal of latent talent in the Institution and are prepared to assist members in the preparation of their papers.

During the year, the Papers Committee arranged for the following Named Papers to be presented :-

The 1954 Sir Alfred Herbert Paper was presented

by The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P., at the Production Conference at Olympia in July, 1954. Lord Halsbury's subject was: "Some Problems of Higher Technological Education" and the meeting was attended by over 600 members and visitors.

The 1954 Viscount Nuffield Paper was presented by Major-General W. A. Lord, C.B., C.B.E., at The Royal Institution on the 19th December, 1954. General Lord's subject was: "The Corps of Royal Electrical and Mechanical Engineers and the Application of Modern Management and Production Techniques".

The 1954 George Bray Memorial Lecture was presented in Manchester on the 18th April, 1955, by Mr. Robert Douglas, M.B.E., Chairman and Managing Director of Dobson & Barlow Ltd. Mr. Douglas chose as his subject: "Engineering and Production Aspects of Synthetic Fibre Manufacture". This was a very interesting paper which attracted a large audience.

These Papers have subsequently been published in the Journal.

The Papers Committee would like to acknowledge the great assistance which they have received from Sections who submitted suggestions for authors and subjects for these Papers.

With the great increase in our activities, more and more widespread publicity for the Institution's aims and objects is being obtained.

Mr. M. Seaman was Chairman of the Editorial Committee for the year and Mr. K. J. Hume was Chairman of the Papers Committee. Both these Chairmen have been re-elected for a further year of office.

Education and Membership Committees

Membership

The new requirements following the Articles of Association adopted in 1954, are now gaining acceptance amongst applicants for membership.

I am pleased to be able to report a continued rise in the membership of the Institution. Because of the new regulations, considerably more applicants are required to quality academically, either by examination or by thesis.

Membership Statistics.

	30th June 1955	30th June 1954
Honorary Members	8	8
Members	1,593	1,526
Associate Members	4,875	4,796
Associates	156	162
Graduates	2,125	2,077
Students	1,125	1,064
Affiliated Firms	219	203
	10,101	9,836
Net increase	265	

"Broadening the Base"

The Education Committee has investigated a number of possible examination structures, giving particular attention, in the recommendations it has made, to the principle of broadening of the base.

Summer School

The 1954 Summer School was held at Ashorne Hill, near Leamington Spa, where the theme was "Practical Training for Production". Over 70 members attended, and in addition there were a number of visitors.

One of the addresses was given by Sir Richard Livingstone, a former Vice-Chancellor of Oxford University, on "The Humanities in Technical Education"; this was widely reported in the National Press and the subject has since been given increasing attention by all concerned with higher education.

Production Engineering Courses Outside the United Kingdom

In Canada, arrangements with the Ryerson Institute of Technology, Toronto, are proceeding satisfactorily, and in May, 1955, the Institution's own examination was held at the Ryerson Institute.

Representation on Other Bodies

National Advisory Council for Education in Industry and Commerce

Following the Report of the Committee under the Chairmanship of Sir Ronald Weeks, to consider the structure of higher technological education in this country, the Minister of Education has accepted the recommendations that a National Award in Technology be established. The Awards will be Diplomas in Technology, with honours for distinguished performances. In the first instance the Award will be comparable to a University First Degree.

Two Boards of Study are being set up, on one of which — that concerned with Engineering — the Institution has been invited to nominate a member. Council decided that Sir Walter Puckey should be asked to accept this important office, and he has agreed to do so.

Manchester College of Technology

The Institution has been asked to advise on the future status of the Manchester College of Technology, and has given its support to the proposal, now in effect, that the College be established as an independent body. Both the Manchester Corporation and the Manchester University have given their agreement.

The Institution has been asked to nominate a representative to the Court of Governors and Mr. F. W. Cranmer has accepted the nomination.

University of Nottingham

The University of Nottingham has also asked the Institution to appoint a representative to the Court and Mr. A. H. Needham has been appointed.

In addition, there are numerous Engineering Advisory Bodies, both locally and regionally, on which

the Institution has been invited to provide representation.

Associate Membership Examination

The 1955 Examination was set during the last two weeks of May; the total number of candidates was 230, which shows an increase of 10 over the previous year. Approximately 55% of the candidates were successful in passing the examination.

During the year, the Chairman of the Membership Committee was Mr. S. A. J. Parsons and the Chairman of the Education Committee was Mr. C. L. Old. Mr. F. Woodifield has been elected Chairman of the Membership Committee for the current year and Mr. R. Ratcliffe has been elected Chairman of the Education Committee.

Research Committee

One of the Committee's tasks during the year has been the compilation of a list of all investigations into problems of production engineering being undertaken at Universities and in industrial research organisations throughout the country. The Research Committee hopes to follow this with offers of assistance wherever it is thought that it might have useful comment to offer. The Committee was very glad to receive a visit from Mr. R. M. McKenzie of the University of Edinburgh and to discuss with him the work which his department is undertaking on the expansion of industry. It was found that there was a number of ways in which the Research Committee could help Mr. McKenzie.

The Research Committee has also considered the possibility of the formation of a study group to co-ordinate the various investigations and developments taking place in the field of Automation. It was felt, however, that the Research Committee was not the correct body to undertake this work and it was recommended to Council that a separate committee be formed for the purpose.

Activities of Sub-Committees

The Material Utilisation Sub-Committee's report was published shortly after the closing of the period which is the subject of this report, but it is felt that this is the proper place in which to record the issue of this most successful volume, which has been very well received. The Research Committee is now considering further investigations on the same lines in fields other than the metal working industries.

The Sub-Committee on Sources of Information has listed some 200 organisations from which, it is felt, information might be obtained by production engineers. A detailed questionnaire was sent to each of these organisations and the Sub-Committee's main task is now to collate these replies and draft the detailed entries for the Directory of Sources of Information. This is a long and complicated process and the Sub-Committee does not expect to have this report ready for publication until late in 1956.

The Report of the Sub-Committee on Production Control (jointly with the Institute of Cost and Works Accountants) was completed during the year under review, but unfortunately, unavoidable delays in the office of the printers prevented its publication as early as was hoped. With the completion of this report the work of the Joint Committee of the Institution of Production Engineers and the Institute of Cost and Works Accountants has been brought to a close, but the Research Committee and representatives of the I.C.W.A. have met and agreed to the appointment of a Standing Joint Committee. The Research Committee is now considering future policy of this Committee in order to submit recommendations to the Council.

The Materials Handling Sub-Committee had, at the end of the previous year, submitted a recommendation that there be established a separate division of the Institution to deal with Materials Handling matters. This proposal has been under active consideration both in principle by a Sub-Committee appointed by the Finance and General Purposes Committee and, in detail as regards Materials Handling, by the Materials Handling Sub-Committee. Indeed, a great deal of that Committee's time has been spent on this work. In addition, however, the Sub-Committee, in October, 1954, organised a Materials Handling Conference in Birmingham which was attended by over 250 members and others. The Sub-Committee also compiled a detailed list of films on Materials Handling and is hoping to be able to see a number of them so that it can report on their usefulness and arrange film shows for the various Sections of the Institution.

The Materials Handling Sub-Committee has also continued its investigations on Cost of Handling and is preparing for publication a series of further case studies with a view to a much more detailed report than any of those which it has previously published.

Specialist Divisions

On the recommendation of the Research Committee, an *ad hoc* committee of the Finance and General Purposes Committee has been set up to consider the possibilities of establishing divisions within the Institution to provide for the specialised interests of groups of members. Materials Handling is being examined as a possible first step and consultations are taking place between the Materials Handling Sub-Committee, the Education Committee and the *ad hoc* committee.

The Chairman of the Research Committee throughout the year was Mr. B. H. Dyson, who has been re-elected for a further year of office. The Chairman of the Material Utilisation Sub-Committee was Mr. R. M. Evans. Mr. Peter Spear was Chairman of the Sub-Committee on Sources of Information, and Mr. F. G. S. English Chairman of the Sub-Committee on Production Control. Mr. T. W. Elkington was Chairman of the Materials Handling Sub-Committee, but unfortunately had to relinquish office due to illness. His place has been taken by Mr. A. G. Hayek. I am happy to be able to report that Mr. Elkington is now fully recovered and is again very active in Institution affairs.

Standards Committee

The Committee has considered 14 Draft British

Standard Specifications during the year and submitted comments on them wherever required. In addition, the Committee has submitted a detailed reply to a request from the British Standards Institution for information as to whether standards are required for General Purpose Iron and Steel Valves and the specific types of valves that might be considered necessary.

The Committee gave detailed consideration to criticisms of B.S.2558 — Tubular Box Spanners — submitted by a member of the Institution and these comments were passed to the B.S.I.

The Committee has appointed representatives on a further four B.S.I. Technical Committees.

In May, 1955, the Committee in co-operation with the B.S.I. organised a Conference of Standards Engineers. This meeting was particularly successful: it discussed the coding of Standards, the issue of loose-leaf data sheets and extension of the use of British Standards. As a result, a Standing Joint Committee of representatives of the B.S.I. and of the Institution of Production Engineers has been appointed to be responsible for calling future conferences. On the recommendation of the May Conference, the B.S.I. has agreed to consider all specifications with a view to issuing data sheets wherever possible.

The publication of an article on Cutting Tool Nomenclature by Mr. G. V. Stabler in the May, 1955, issue of the Journal has led the Standards Committee to go into this question in considerable detail. At one meeting, Mr. Stabler and a representative from PERA were present and their views — often conflicting — were discussed at length. The Committee's work in this connection is proceeding.

During the year, the Standards Committee devoted some of its time to considering what action it could take with regard to publicity for standardisation. It began the preparation of a report showing how many standardisation suggestions had been passed to B.S.I. over the years and what had been the result of these suggestions. It is hoped that this report will be published during the year 1955/56.

The Standards Committee feels that it has its part to play in the Institution's developing interest in automation and has begun detailed consideration of the possibility of standardising transfer units, with special reference to the actual machine heads as opposed to the means of transferring components or complete machine tools.

The Committee has referred to the B.S.I. a problem felt by a number of members of the Institution with regard to obtaining information about international standards. Such information is of vital importance to members whose companies are engaged in the export trade and it is hoped that the Standards Committee will have something definite to report before very long.

The Chairman of the Committee during the year 1954/55 has been Mr. R. E. Mills, who has been re-elected for a further year.

Hazleton Memorial Library Committee

During the period under review about 200 books were added to the Library, which now comprises about 4,000 books and pamphlets besides the files of about 300 periodicals. The Library was steadily used by all sections of the Institution; it issued an average of 191 books per month and answered an average of 102 enquiries. Most of the business is done by post and telephone, although an increasing number of members, attracted no doubt by the improved premises, are visiting the Library personally. It is hoped that the publication of the catalogue will encourage more members to use the Library.

The Library co-operates with the National Central Library, ASLIB, the Science Library, the libraries of kindred institutions and many other special libraries. Were it not for this system of mutual help, many books and much information would not be available to users of our Library, itself regarded by other libraries as a source of information on books on metalworking and machine tools.

The Committee again wishes to express its thanks to the members who review and abstract books added to the Library.

The Chairman of the Committee during the period was Lord Sempill, who has been re-elected for a further year of office. The Chairman of the Book-Selection Sub-Committee was Mr. J. C. Z. Martin who has also been re-elected for a further year.

The work of our Standing Committees is invaluable to the Institution and I should like to express here my sincere appreciation, on behalf of the Council, for the loyal and conscientious service which the Chairman and members of the Standing Committees give to the Institution.

Regional and Section Activities

Regional and Section activities have gone from strength to strength; 308 Section lecture meetings and four Regional lecture meetings have been held in the United Kingdom, and over 50 meetings have been held in Sections outside the United Kingdom. In addition, many successful social functions have been arranged and numerous interesting works visits have been organised.

The Regional Plan has now been in operation for twelve months. In the more closely-knit Regions arrangements are working very satisfactorily and a spirit of Regional co-operation is being achieved. However, in some of the Regions geographical considerations make it very difficult for arrangements to operate effectively, but the scheme is sufficiently flexible to allow each Region ample freedom and it is hoped that as time goes on Regional activities will become more and more firmly established.

The Southern Section again organised a Conference — the third in the series — on "Problems of Aircraft Production" which was held at the University of Southampton in January, 1955. The Conference attracted considerable interest and, in spite of the fact that a blizzard raged throughout most of the duration of the Conference, all the sessions were filled to capacity. This Conference has now achieved a very high standard and the Southern Section are to be congratulated on their initiative in developing this extremely valuable activity.

The Cornwall Section promoted a Conference on the subject of "Compressed Air as an Aid to Productivity". The Conference was held in Camborne at Easter and although Camborne is such a very great distance from the main centres of industry over 100 members and visitors attended, more than half of whom journeyed to Cornwall from other parts of the country. The success of this venture was very gratifying and the Cornwall Section are considering repeating the function in the near future.

The Conference of Regional Officers was held in January, when the Regional Plan was fully discussed and many valuable suggestions were made for improving the arrangements.

The annual Conference of the Section Honorary Secretaries was held in May and valuable discussions took place on the administrative problems of the Institution.

Our Graduate Sections still continue to play a very active part in the affairs of the Institution. I have already referred to the interesting discussion on "The Place of the Graduate in the Institution" which was held at a Council meeting, when representatives of Graduate Sections were present. The London Graduate Section and the Halifax Graduate Section both organised Week-end Schools. A Conference of representatives from all the Graduate Sections was arranged by the Wolverhampton Graduate Section in March. Although the purpose of this Conference is to discuss particular administrative problems of the Graduate Sections, many points of Institution policy were discussed and those Graduates who attended felt that they had a very satisfactory meeting.

Not the least valuable aspect of all these various activities throughout the Institution is the opportunities which they provide to renew old acquaintances and to make many new friends.

Honours

Her Majesty The Queen has been graciously pleased to confer honours on a number of members of the Institution whose names I give below :-

Knight Bachelor

H. Spurrier.

C.B.E.

F. W. Halliwell; H. W. Hobbs; B. A. Williams.

M.B.E.

E. Ayland; W. G. Bennett; J. W. Gardner.

O.B.E.

R. A. Wright.

I am sure that all will join with me in congratulating these members on the Sovereign's recognition of their services to the Realm.

Obituary

It is with deep regret that the deaths of 30 of our members during the year must be recorded. Their names have been published in the Journal.

Headquarters Staff

I have already referred to the problems of staffing which we have had at our Headquarters during the year but I should like this opportunity to record our appreciation of our Senior Staff. In Mr. Woodford we have an exceptional Secretary and the time he gives to Institution business out of normal working hours, often ably supported by Mrs. Woodford, constitutes a very considerable burden which he carries as if it were no burden at all.

Again, he and the Institution, have been loyally served by his three lieutenants — Miss Bremner, Mr. Badger and Mr. Caselton.

We were very sorry indeed to lose the services of Miss P. Cooper, B.A. (now Mrs. Steane) who relinquished her appointment as Hazleton Memorial Librarian in December, 1954, subsequent to her marriage. When the Hazleton Memorial Library was constituted after the War, Miss Cooper was given charge of the Library; she did invaluable work in creating the fine Library which we now have and in building up the information service which has proved of such great use to all those members who have occasion to require this facility. The Council would like to place on record its appreciation of Mrs. Steane's services to the Institution and to wish her well in her future life.

Miss M. South, B.A., F.L.A., has been appointed as Librarian and has already proved herself to be an able successor to Mrs. Steane.

Awards

On the recommendation of the Papers Committee, the following awards for Papers were made during the year :-

Institution Medal for the Best Paper presented to a Section by a Member : To Mr. K. J. Hume, M.I.Mech.E., M.I.Prod.E., for his Paper on "Fundamentals of Gauge Design".

Institution Medal for the Best Paper presented to a Section by a Non-Member : To Mr. F. Nixon for his Paper on "The Effective Utilisation of Materials".

The Hutchinson Memorial Award (for the Best Paper presented to a Section by a Graduate) : To Mr. G. Cubitt-Smith for his Paper on "Resistance Welding in America".

Schofield Travel Scholarship : To Mr. W. R. Bailey, Grad.I.Prod.E.

The Lord Austin Award : (This award had not been confirmed at the time of going to press.)

Services of Members

I am able again to record with great pleasure the Council's keen appreciation of the enormous services rendered to the Institution by many members during the course of the year. Members are able to serve the Institution in a variety of ways; they can serve on Committees, they can represent the Institution on other organisations, they can assist with the work of the Standards Committee, they can help the Library by reviewing or abstracting new books, and in many other ways.

I am quite sure that there must be many other members who would like to give service to the Institution if opportunities were provided. To enable us to keep much closer contact with the generality of members and to make greater use of the enormous

body of knowledge which is available, a new index of members, showing their special interests, is in course of being established at Headquarters. I hope that this new index when it is fully operating will enable us to offer many more members the opportunity of rendering service to their profession.

The President

At the end of June, 1955, Sir Walter Puckey's period of office as President came to an end. Sir Walter relinquished office having served the Institution continuously as a Principal Officer for seven years; first as Vice-Chairman of Council, then Chairman of Council, then as Vice-President, then President-elect and, finally, as President, which is the highest office of all to which a member can aspire.

Sir Walter's record of service is unique in the Institution and to make some small token of appreciation, a special dinner party was held in the House of Lords, through the very kind offices of Lord Sempill and by permission of the Lord Great Chamberlain, at which Sir Walter was presented with a silver tray on which was engraved the facsimile signature of every member of Council in the United Kingdom. It was fortunate that Mr. H. Le Cheminant, an old and valued member of the Institution, was on a visit to this country from Australia: we were thus able to invite him to this special dinner as representing our members outside the United Kingdom and to include his signature on the silver tray.

I find it difficult to find words adequately to express our great respect and affection for Sir Walter. More often than most he seems to be gifted with those flashes of inspiration which have such a profound and progressive influence on the future of our Institution. I, personally, as a member of the Finance and General Purposes Committee working under his Chairmanship, and as Vice-Chairman and Chairman of Council working under his Presidency, have received stimulation, edification and sometimes provocation for which I shall always be in his debt.

Looking Ahead

The possibilities that lie ahead of production engineers are immense. The technological discoveries and inventions of the past decade or so offer to production engineers a great challenge. They open up entirely new methods of production which will have the most profound effect upon our standard of living. These technological changes will, in their turn, bring the most complex problems of human relations. These human problems are as much a concern of the production engineer as the purely technical ones, and the Institution of Production Engineers, not only as a corporate body, but through the personal activities of each of its members, has a unique opportunity of bringing lasting benefit to mankind.

JOURNAL BINDERS

Strongly-made binders for the Institution Journal, each holding 12 issues, may be obtained from Head Office, 10 Chesterfield Street, London, W.1, price 10/6 each, including postage.

RESEARCH PUBLICATIONS

Production Engineering Research Association, "Staveley Lodge", Melton Mowbray, Leics.

A number of copies of the following Research publications are still available to members, at the prices stated:

These publications may be obtained from the

Machine Tool Research and Management	10/6
Report on Surface Finish, by Dr. G. Schlesinger	15/6
Practical Drilling Tests	21/-

THE INSTITUTION OF PRODUCTION ENGINEERS

BALANCE SHEET as at 30th JUNE, 1955.

1954 £	1954 £		£	£	1954 £	1954 £		£	£
		Accumulated Funds and Surplus					**Fixed Assets**		
25,000		The Viscount Nuffield Gift ...	25,000		35,000		Freehold Premises: At cost ...		35,000
500		The Lord Austin Prize Fund ...	500				Freehold Premises: Cost of Alterations and Equipment, *less* Donations, Reserves, etc.		
100		The Hutchinson Memorial Fund	100				Balance as 1st July, 1954 ...	4,964	
500		The George Bray Memorial Fund	500				Deduct receipts *less* expenditure during year	2,151	
	26,100			26,100		4,964			2,813
	464	Special Reserve		—			Furniture, Fittings and Plant at the net amount standing in the Institution's books at 30th June, 1948	1,531	
	—	Renovations Reserve		500			Additions	6,445	
	895	Life Subscriptions: *Less* amount transferred to Income and Expenditure Account ...		1,014				7,976	
	10,652	Income and Expenditure Account		17,738			*Less* Depreciation to date ...	3,123	
	38,111			45,352		3,627			4,853
	250	Hazleton Memorial Library Catalogue		—			Fund Investments at cost: as scheduled (Market Value £1,056)		1,100
	56	Melbourne Prize Account ...		56		1,100			
	235	Schofield Scholarship		131					43,766
	500	Production Exhibition and Conference		—		44,691	**Current Assets**		
	76	Work Study Symposium: South Africa		85			Sundry Debtors, Deposits and Stocks	12,897	
		Current Liabilities					United Building Society—Deposit (South Africa)	2,097	
16,646		Sundry Creditors	12,055			9,529			14,994
	313	Subscriptions Received in Advance	466						
	49	Bank Overdraft: *Less* Sections and Cash Balance	615			2,016			
	17,008			13,136		11,545			
	£56,236			£58,760		£56,236			£58,760

SIR WALTER PUCKEY, *President.*

G. R. PRYOR, *Chairman of Council and Finance Committee.*

W. F. S. WOODFORD, *Secretary.*

Report of the Auditors to the Members of The Institution of Production Engineers.

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit. In our opinion proper books of account have been kept by the Institution so far as appears from our examination of those books. Audited Balance Sheets and Accounts have been received from each of the Overseas Sub-Councils and these have been incorporated in the above Balance Sheet and annexed Income and Expenditure Account. We have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account audited by us and the audited Sub-Councils' Accounts supplied to us. In our opinion and to the best of our information and according to the explanations given us the said Accounts give the information required by the Companies Act, 1948, in the manner so required and the Balance Sheet gives a true and fair view of the state of the Institution's affairs as at 30th June, 1955, and the Income and Expenditure Account gives a true and fair view of the excess of income over expenditure for the year ended on that date.

20 Bloomsbury Square,
London, W.C.1.

29th November, 1955.

GIBSON, APPLEBY & CO.,
Auditors,
Chartered Accountants.

INCOME AND EXPENDITURE ACCOUNT for the Year ended 30th JUNE, 1955.

1954 £	£		£	£
		To **Establishment Charges**		
591		Rates	971	
1,259		Light, Heat and Cleaning	1,551	
289		Repairs and Renewals ...	246	
	2,139			2,768
		„ **Administration Expenses**		
2,156		Postage and Telephone ...	1,993	
3,648		Printing and Stationery ...	4,562	
		Professional Charges and		
364		Insurance	122	
200		Audit	200	
		Travel, Entertaining and		
		Meetings (other than		
1,475		Sections	1,594	
420		Miscellaneous	15	
	8,263			8,486
	14,874	„ **Salaries**		16,757
		„ **Section Expenses**		
2,209		United Kingdom	1,977	
2,499		Overseas (Audit Fees £98)	2,301	
1,162		Central Services	1,351	
	5,870			5,629
		„ **Journal**		
23,056		Printing	26,975	
2,465		Postage and Envelopes ...	2,860	
222		Reporting	209	
	25,743			30,044
	251	„ **Institution Papers**		299
	421	„ **Hazleton Memorial Library**		223
	208	„ **Donations and Grants** ...		113
		„ **Miscellaneous**		
338		Annual Dinner, 1954 ...	12	
426		Year Book	100	
100		Summer School	117	
	864			229
		„ **Provisions**		
		Depreciation — Furniture		
567		and Fittings	762	
		Hazleton Memorial Library		
250		Catalogue	—	
		Production Conference and		
500		Exhibition	—	
	1,317			762
	—	„ **Renovations Reserve** ...		500
		„ **Balance**—Excess of Income		
		over Expenditure carried		
	2,590	down		7,072
	£62,540			£72,882

1954 £	£		£	£
		By **Subscriptions**		
28,832		Renewals and Arrears ...	30,292	
311		Transfers	341	
1,360		New	957	
4,311		Overseas	4,309	
796		Entrance Fees	542	
—		Registration and Miscella-		
		neous Fees	689	
—		Recovery of Income Tax on		
		Subscriptions	5,546	
	35,610			42,676
	804	„ **Interest**		136
	26,078	„ **Journal Receipts**		29,597
	48	„ **Sale of Publications**		10
	—	„ **Conferences**		432
	—	„ **Miscellaneous Receipts** ...		31
	£62,540			£72,882

APPROPRIATION ACCOUNT

1954 £		£	£	1954 £		£
3,027	To Loss on Sale of Securieties ...		—	10,070	By Balance at 1st July, 1954	10,652
	„ Transfer to New Building Fund:				„ Excess of Income over Expenditure brought	
—	New Zealand	100		2,590	down	7,072
—	South Africa	350		1,019	„ Profit on Sale of Lease	—
		—	450	—	„ Transfer from Special Reserve	464
10,652	„ Balance carried forward... ...		17,738			
£13,679			£18,188	£13,679		£18,188

INVESTMENTS AT COST, 30th JUNE, 1955.

	£	£
The Lord Austin Prize Fund		
£95 8s. 5d. 3½% War Stock	100	
£575 8s. 3d. London County 3% Consolidated Stock, 1920	400	
	—	500
The Hutchinson Memorial Fund		
£95 8s. 5d. 3½% War Stock		100
The George Bray Memorial Fund		
£775 0s. 9d. London County 3% Consolidated Stock, 1920		500
(Market Value £1,056 10s. 4d.)		£1,100

THE INSTITUTION OF PRODUCTION ENGINEERS

SUMMARY OF INCOME AND EXPENDITURE ACCOUNT

for the Year to 30th JUNE, 1955.

Expenditure	£	£
United Kingdom		63,490
Outside the U.K.: Australia	1,081	
Bombay	215	
Calcutta	142	
New Zealand	20	
South Africa	650	
Canada	212	
		2,320
Excess of Income over Expenditure		
United Kingdom		4,888
Outside the U.K.: Australia	818	
Bombay	151	
Calcutta	335	
New Zealand	129	
South Africa	524	
Canada	227	
		2,184
		£72,882

Income	£	£
United Kingdom		68,378
Outside the U.K.: Australia	1,899	
Bombay	366	
Calcutta	477	
New Zealand	149	
South Africa	1,174	
Canada	439	
		4,504
		£72,882

ANALYSIS OF ASSETS AND LIABILITIES at 30th JUNE, 1955.

	U.K. £	*Outside U.K.* £
Accumulated Funds and Surplus	39,446	5,906
Melbourne Prize Account—Australia		56
Schofield Scholarship	131	
Work Study Symposium—South Africa		85
Current Liabilities		
Sundry Creditors	11,708	346
Subscriptions Received in Advance	349	119
Bank Overdraft—United Kingdom	4,804	
	£56,438	£6,512

	U.K. £	*Outside U.K.* £
Fixed Assets		
Freehold Premises	37,813	
Furniture, Fittings and Plant	4,663	190
Fund Investments	1,100	
	43,576	190
Current Assets		
Sundry Debtors, Deposits and Stocks	12,862	35
Investments—South Africa		2,097
Cash at Bank and in Transit		
United Kingdom	—	
Australia		2,059
Bombay		87
Calcutta		944
New Zealand		397
South Africa		465
Canada		238
	£56,438	£6,512

Hazleton Memorial Library

REVIEWS & ADDITIONS

"The Automatic Factory — A Critical Examination." *Fittsburgh Publishing Co.*, 1955. 81 *pages. Illustrated. Diagrams.* $1.50.

This little book of something under 80 pages will be of interest to those who are considering the installation of automatic transfer mechanisms. It is a report by a student team from the manufacturing course of Georges F. Doriot at the Harvard Graduate School of Business Administration. The team spent six months in research on this problem and claim that they interviewed the leading authorities and read the literature of this fascinating subject. Their chief objective was to bring the automatic factory into proper perspective and they claim that the report attempts to bridge the gap between theoretical concepts and the actual industrial developments of the automatic factory.

The last 15 pages are devoted to a detailed report involving cost comparisons of the "Tinkertoy" project — a new method of manufacturing electronic equipment — which was prepared by a group of consultants for the Department of the Navy, Bureau of Aeronautics, of Washington. The report includes a comparison between automatic and hand assembly and is particularly useful because it provides both diagrams and tables relating to costs.

Turning now to the remainder of the book which was prepared by these seven authors: the first chapter contains a thesis of the report, while the remaining chapters support these conclusions. The following chapter consists of a clarification of what they term "the state of confusion" which arises from the different meanings ascribed to that new word "automation". The authors point out that each of the contributing industries, comprising manufacturers of automatic handling equipment, the machine tool makers, the providers of electrical and electronic apparatus, and others, tend to think of their particular contribution as "automation", whereas, of course, the word (which was originated by a Vice-President of Manufacturing of the Ford Motor Company and was intended to describe interoperation mechanisms) is now comprehensive.

The next chapter deals with the growth of mechanisation and the tendency towards complete automaticity. It describes the elements of the automatic factory and refers to the open and closed loop control system. Following this, there is in Chapter 4 a discussion of the obstacles in the path of progress towards the automatic factory. It breaks down into four classifications, viz: the complexity of the process; the lack of qualified personnel; the decentralisation of essential skills, and the high cost of development. In regard to the decentralisation of essential skills, it is shown that this results in a lack of co-operation between the machine tool builders and the other contributors to automation.

Chapter 5 deals with contemporary examples of automation and there are some excellent photographs to illustrate the examples given. The next chapter gives eleven case studies relating to costs. This, also illustrated by photographs, is probably the most useful portion of the book. In Chapter 7, the social implications of the automatic factory are discussed. The conclusions reached in this chapter do not differ much, if at all, from the conclusions that have been reached in this country. They do say, among other things, that "individual managements should assume responsibility for their employees displaced or replaced by automatic techniques".

The final chapter is devoted to the future and here there is a discussion of the factors in industry contributing to the trend of the wider use of automation among which there are three that may be mentioned here: "Competition among equipment manufacturers; competition among equipment purchasers, and the return of the buyers' market", the latter probably being the greatest urge. The authors also discuss the areas in which they expect the greatest advances in automation to be made in the near future. This book is interesting in that it presents, in concise manner, the reaction of the members of the American public to automation. F.G.W.

"Quality Control" by Norbert L. Enrick. *Second ed. Industrial Press, New York. Machinery Publishing Co., Brighton*, 1954. 181 *pages. Diagrams.* £1. 17s. 6d.

The author has succeeded in writing for the practical man a book on the procedure for quality control operation.

Part I describes the fundamentals of inspection methods; procedures required for installing lot-by-lot inspection; sampling and process inspection methods; and the introduction and application of quality control methods into a plant. Tolerances and allowances, variability of products, basic dimensions and standardisation of tolerances and allowances are simply explained. A small section covers unified and American standards for screw threads. Mass Production gauging with its limiting factors, and the use of inspection data in establishing specifications are described. Sections on the management aspect of quality control, a typical case history, the statistical basis of modern quality control, the mathematical theory of control charts, and a mention of special control charts for use with old and worn machinery, complete the first part.

Part II utilises examples from semi-continuous and continuous processes, as against piece-part manufacture in Part I. Further product variability, standard deviations, practical applications, the computation and use of control charts, acceptance control charts, and analysis of variance are discussed.

Although not a book for the expert, it may be read with advantage by those wishing to broaden their views on the subject and gain an insight into the American concept of modern control. C.T.J.

"Personnel Management: Principles and Practice" by C. H. Northcott. *Third edition. Pitman, London*, 1955. 427 *pages.* £1. 10s. 0d.

This is the third edition of the author's "Personnel Management: Its Scope and Practice", the second edition of which was published in 1950. The sub-title has been altered to indicate a change in contents, which are now divided into two sections. The first, which deals with principles, comprises chapters on Organisation and the Place of Personnel Management; Aims and Principles in Industry: Policies and Procedures; Incentives; Working Environment: Psychology; Industrial Relations; and Joint Consultation. The second part deals with the practical applications of the principles; the Working of a Personnel Department; Employment; Records; Selection and Training; Wages; Education: Health and Safety; Welfare Services; and Industrial Relations in Practice.

The author, who is a former Director of the Institute of Personnel Management, and a former Labour Manager of Rowntree and Company, illustrates his book with practical examples. The book is well documented and includes a bibliography.

" Organic Protective Coatings " Editors: William von Fischer and Edward G. Bobalek. *Reinhold, New York,* 1953. 387 *pages. Illustrated. Diagrams.* £3. 10s. 0d.

This work commences by introducing ' paint ' as an engineering material of today, as compared with the nineteenth century, when painting was considered artistic through the medium of a paint brush.

The reason for this, the author reveals, is that through constant research over the past 30 years, science has developed a greater understanding of the crystalline structure of basic materials surrounding the problems of corrosion inhibition. Therefore, the decorative properties of the film became secondary to those possessing corrosion resistance of protective value, although with the more recent coatings, technology has improved the corrosion protective properties without sacrificing any of the decorative or colour properties of the ancient art.

Where previously colour matching was the technique, today paint formulation is a formula of engineering requirements.

Rapid application of coating became successful through the discovery of synthetic resins and pigments, together with the engineering development of the spray gun. Coatings technology and development are next discussed, thoroughly pursuing the principles of paint formulation, pigment dispersion and various anti-corrosive pigments.

Relative absorption and reflectance of pigments follow, considering at length luminescent coating characteristics and reflectance sprectrophotometry. Pigment research over the past 25 years has developed new type pigments, which are next clearly illustrated for use in modern colour design.

The authors then present a thesis on the chemistry and physics of vinyl and amino-plast resins, clearly defining their status in industry today. A practical discussion follows, penetrating the history and properties of various types of wood, together with their relative effect on paint performance. Also, considerable details are given of hot spray lacquers, the control of physical constants and film formulation, plus recent industrial progress.

Emulsion and latex type paints are next pursued, examining film structures and the basic principles involved in formulation, followed by a discussion on the advantages and disadvantages of such coatings, and for metal protection, synthetic resin coatings are briefly reviewed.

Organic coatings for electrical insulation are then discussed, giving an insight into the various resins and methods employed over the past century, together with the more recent epoxy type resins. Finally, a compact study is made of the silicone resins in heat-resistant paints, with a brief reference to the chemistry and physics, plus the results of many life and exposure tests, leaving the reader with an eye to the future.

This volume, similar to its predecessor by von Fischer, " Paint and Varnish Technology ", is one of a lecture series held at the Case Institute of Technology, Ohio, and once more the editors are to be complimented on their admirable selection and presentation. There is complete continuity: for the student this volume could be his " 2nd year "; for the manufacturer and industrial user, the work contains a wealth of information for inclusion in the library.

It is disappointing to note, however, the briefness of the section on mechanisms of film failure, as this section is of great importance to the industry and could have been expanded.

The work is clearly defined, using many illustrations and bibliographical references of up-to-date knowledge.

H.B.J.

" Engineering Works Practice." *Four volumes and Data Sheets. Newnes, London,* 1955. £8. 10s. 0d.

A collective work covering many branches of engineering production related subject matter.

Vol. I. Patternmaking and Foundry Practice, Machine Shop Practice, Forging and Smithing.

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The Data Sheets cover screw threads, Newall limits, etc., and also the features of a number of principal makes of machine tools. The work is generously illustrated with photographs and line diagrams, and is well indexed. The subject matter is comprehensive rather than its treatment.

A.J.L.

" Vapor-plating: The Formation of Metallic and Refractory Coatings by Vapor Deposition " by C. F. Fowell and others. *Wiley, New York. Chapman & Hall, London.* 1955. 158 *pages.* £4. 4s. 0d.

When I saw this book, I thought that here we had a new process and perhaps the American authors were out to sell it. The process, however, is not new—the most familiar example to most of us being nitriding.

The book consists of 142 pages of concentrated technical data, much of which was out of my depth, dealing as it does with the chemical side of the process. Unfortunately, there is not much information of real value to the production engineer. The saving grace is that the book is divided up into very well defined sections; consequently, reference to vapour plating say, by borides, is very easily found.

When discussing metal vapour plating, there is a note at the end of each section describing the properties of the coating. This I found to be of considerable interest. Unfortunately no information is given on the economics of a particular process or snags one could be expected to find. To compensate for this, there are most copious references at the end of each chapter which, I should imagine, would give information more useful to us.

As I said at the beginning, nitriding is the process with which we are all probably most familiar. I made this remark to show that the term " Vapor plating " has been used in this book only to describe the chemical process in which the metal is carried in the form of a vapourised chemical compound over a component at a considerably higher temperature. This must not be confused with the physical process in which the metal vapour condenses on a detail which is kept at a much lower temperature.

The vapour coating by metals, carbides, nitrides, borides, siliacides and oxides are all discussed.

I gained the impression that—illustrious as the authors are—they compiled this book mostly from written works rather than actual practice.

I consider the book to be a very comprehensive review of the field of vapour-plating in a purely technical sense, but I am afraid it is of very little use to the production engineer.

R.E.M.

" Oxford Junior Encyclopaedia." Vol. VIII—Engineering. *Oxford University Press, London,* 1955. 496 *pages. Illustrated Diagrams.* £1. 10s. 0d.

I do not know why this book is called a " Junior ", unless it covers all juniors from 8 to 80 because they have young, agile minds. To my mind, an engineering encyclopaedia should explain things in a manner which assumes in the reader a sound basic sense and an ability to comprehend. This work does just that. There is not a word in its 500 pages that I would not hesitate to quote before any body of engineers if I wanted to explain a point or define something. My only complaint is the definition of production engineering, which only covers the mass production aspect. However, it goes on to explain the true meaning of production engineering as we understand it.

All aspects of engineering are covered — Civil, Mechanical, Electrical and Aeronautical, besides power science and mathematics. All other forms of engineering come under the heading of special engineering.

This work is written in a very sober and conservative manner, and very carefully avoids anything too spectacular. Fundamentals are explained well and logical steps are described and well illustrated.

To cover the whole field of engineering in 500 pages is obviously an impossible task, and it would not be difficult to notice the omissions. A very good sense of balance has, however, been obtained and no attempt has been made to try and cramp too much into the space provided. Engineering is naturally a subject which advances very rapidly, and books of this kind can date quickly. This Encyclopaedia is right up to date without indulging in "futuristic fancifying", so it should hold its place for a few years to come.

The Librarian made a special plea to me to review this book quickly, as she was using it regularly for reference. I recommend that the book be kept as a reference book rather than be lent out, and I also recommend that we should not hesitate to follow her example.

R.E.M.

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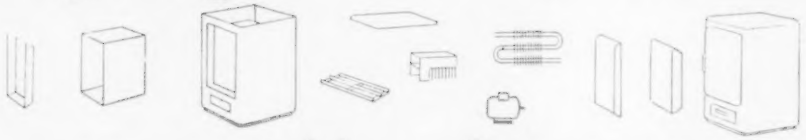

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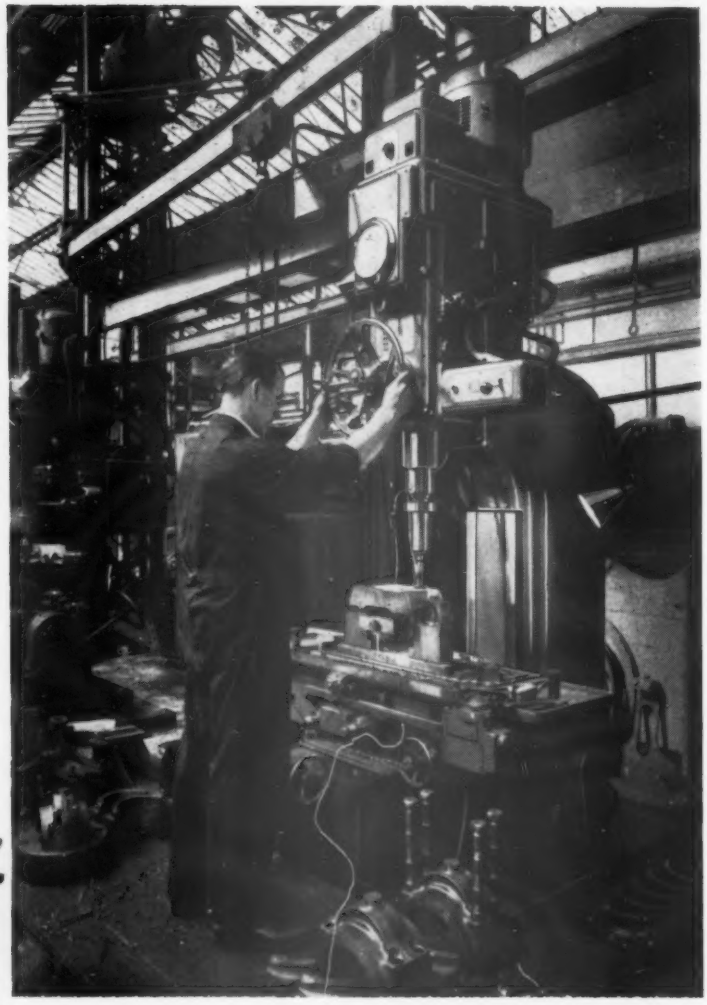

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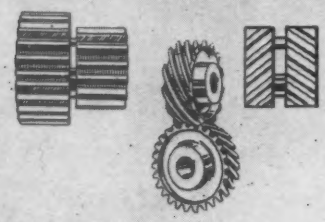
SUNDERLAND



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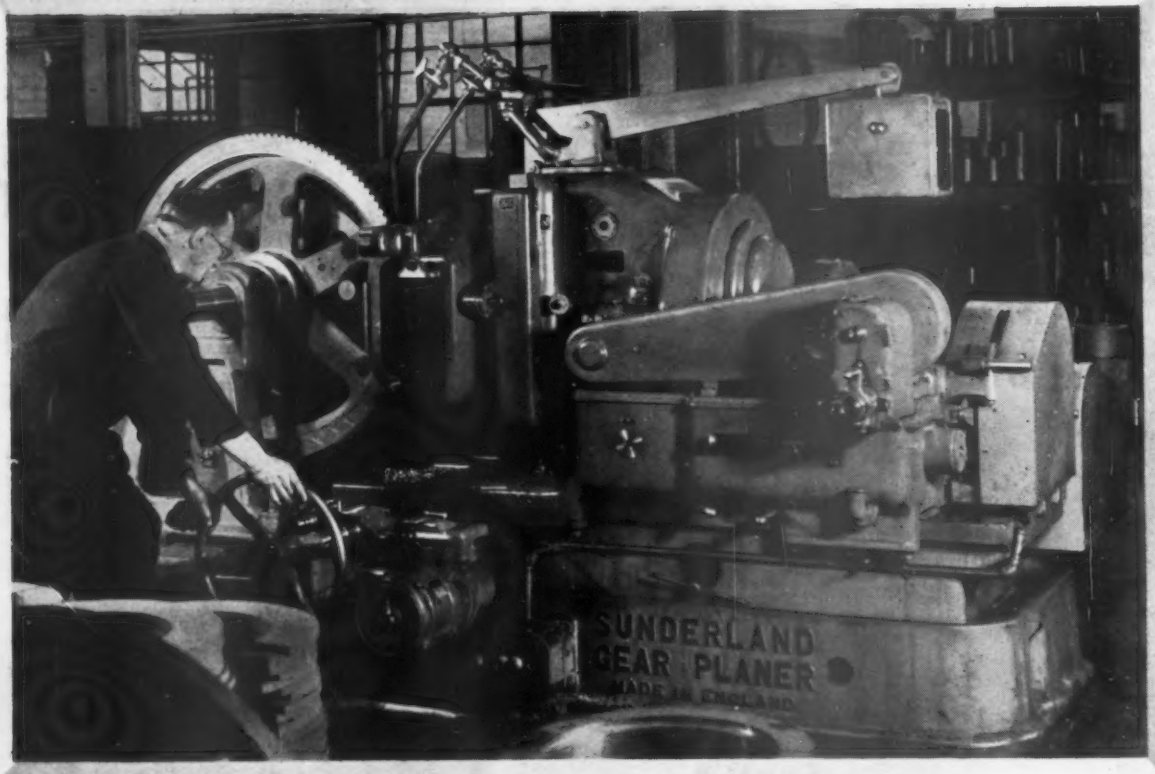

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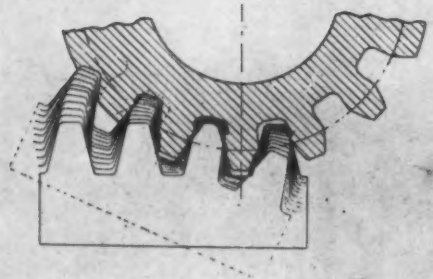

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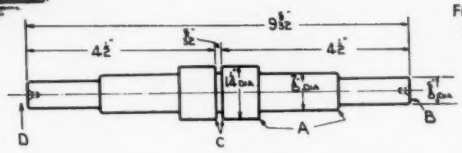

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1⅛" dia. Steel Bar, En.8. Made in pairs.

All Tungsten Carbide Cutting Tools

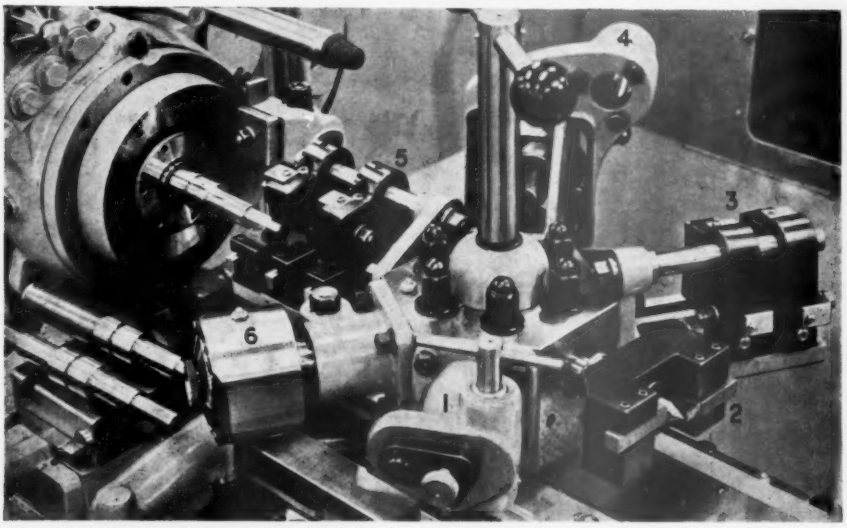
Ward

Nº 2C CAPSTAN LATHE

RACK PINION SHAFT

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Feed to Stop, Chuck and Centre	1	—	—	—	Hand
2. Start Turn ⅝" dia.	2	—	1020	350	Hand
3. Multiple Roller Turn ⅝" and ⅞" dias.	3	—	1020	350	216
4. Knee Turn Gear Dia. 1¼"	4	—	2041	700	216
5. Face End B and Radius Shoulders A	5	—	2041	670	Hand
6. Double Radius Gear C	—	Front	2041	670	Hand
7. Feed out for Double Length	6	—	—	—	—
8. Support and Part-off D	6	Rear	2041	670	Hand
9. Re-chuck and repeat Operations 1, 2, 3, 4, 5					

Floor to Floor Time 2¾ minutes One End 4¾ minutes Complete



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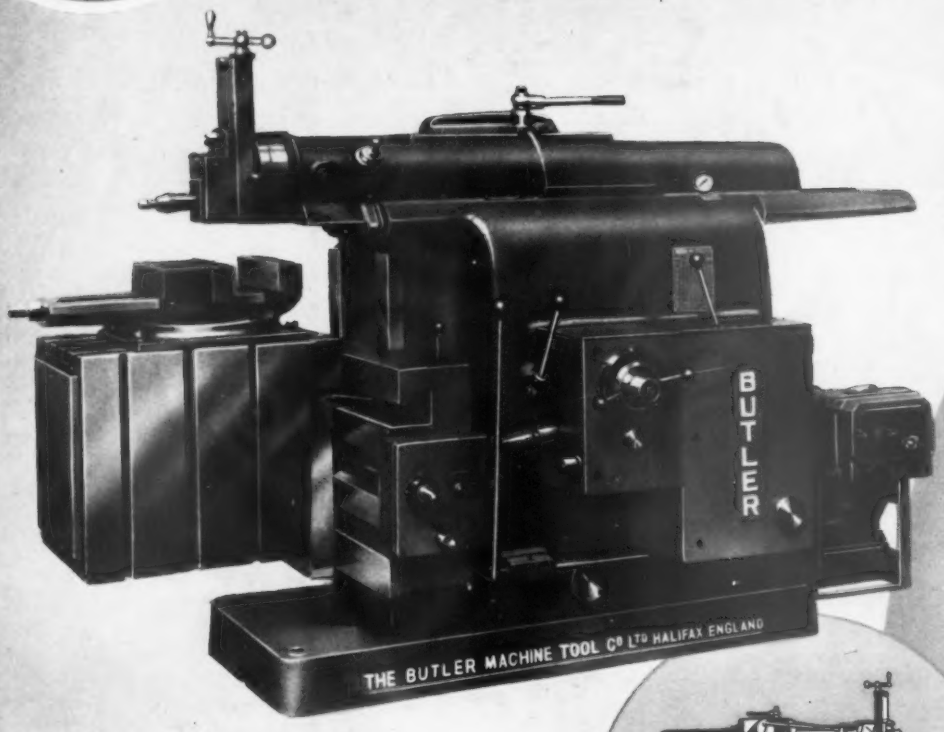

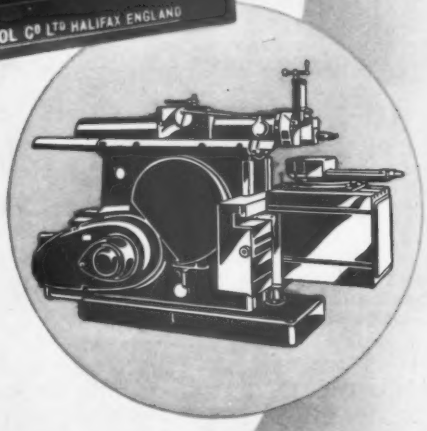

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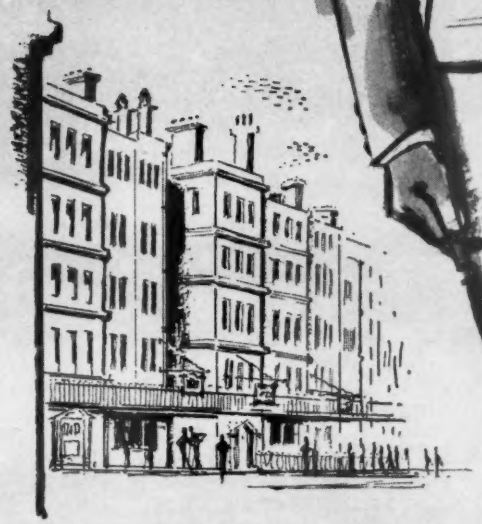

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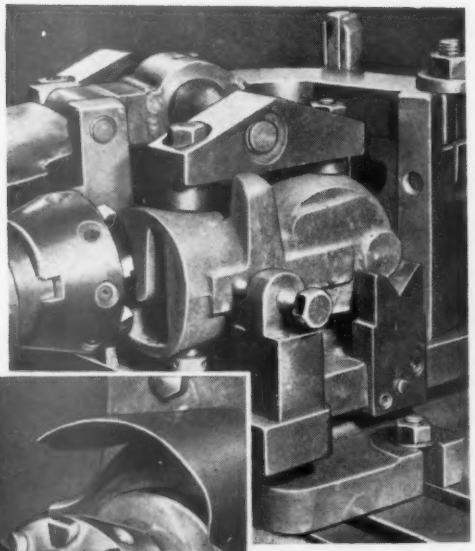

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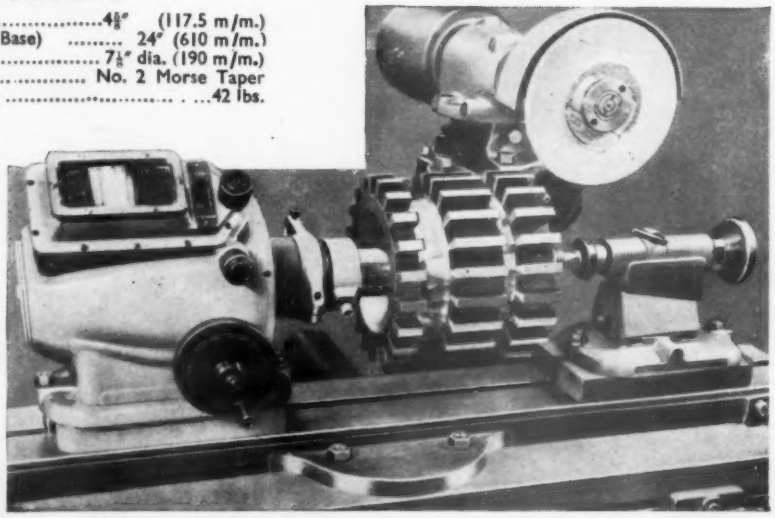

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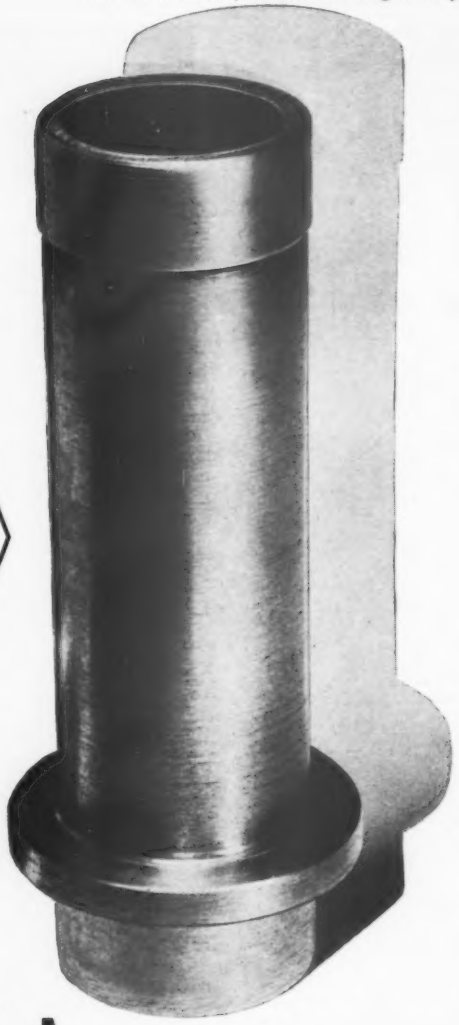
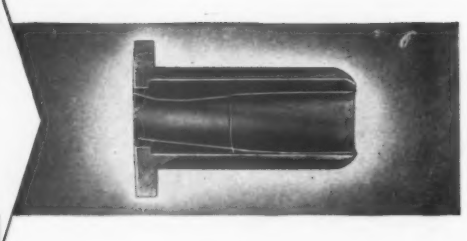


Seeing is believing !

The photographs below show the results of a comparative test made between a Tungsten Carbide Nozzle and a Carbon Tetra Boride Nozzle used with carborundum shot at an air pressure of 75-100 lbs per sq. inch.

The $\frac{3}{16}$" bore Tungsten Carbide Nozzle was worn to this condition in *two* weeks.



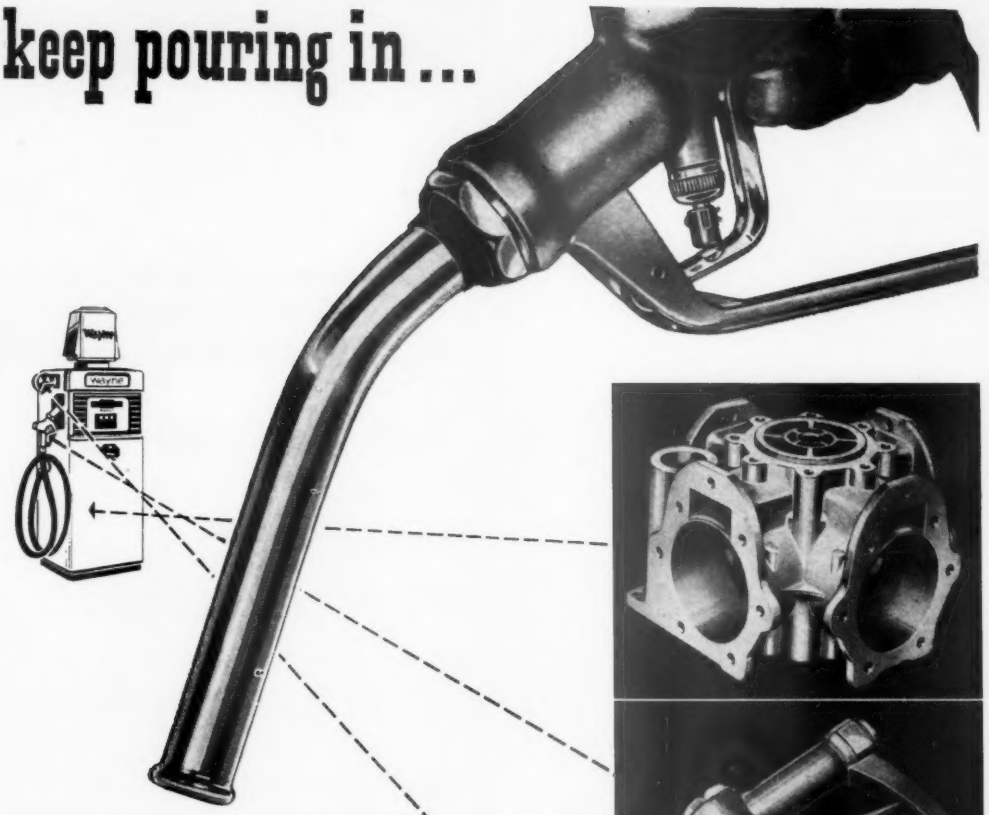
The $\frac{3}{16}$" bore Carbon Tetra Boride Nozzle with tapered lead-in was worn to this condition in *eight* weeks.

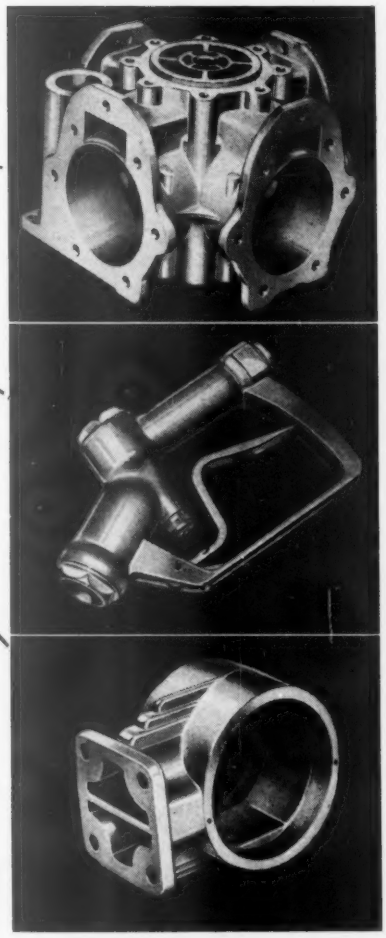
Glostics Ltd

AGENTS · IMPREGNATED DIAMOND PRODUCTS LTD

TUFFLEY CRESCENT · GLOUCESTER

Orders keep pouring in...





Make a
better mouse-
trap and the world
beats a path to your door.
And the saying holds good whether
it be mousetrap or machine tool, door lock
or duplicator, fishing reel or food mixer, printing
plant or petrol pump. Whatever the product if it meets the
needs of the customer and is at the right price—orders will come
pouring in. Today the problem is how to keep pace with demand.
Certainly it applies in our case. In order to satisfy demands from new
customers we have undertaken a major development programme. The
installation of a considerable amount of plant is now complete, enabling
us once again to turn our attention to enquiries from new customers.

Wayne Tank and Pump Co., Ltd., are old friends of ours. We illustrate a few of the more recent castings made by us for their latest model.

30 YEARS' ANGLO-AMERICAN DIE CASTING EXPERIENCE

WOLVERHAMPTON DIE CASTING
AFFILIATED WITH
PRECISION CASTINGS CO. INC. (U.S.A.)

CERTIFIED ZINC ALLOY ZAMCA DIE CASTERS

THE WOLVERHAMPTON DIE CASTING COMPANY LIMITED

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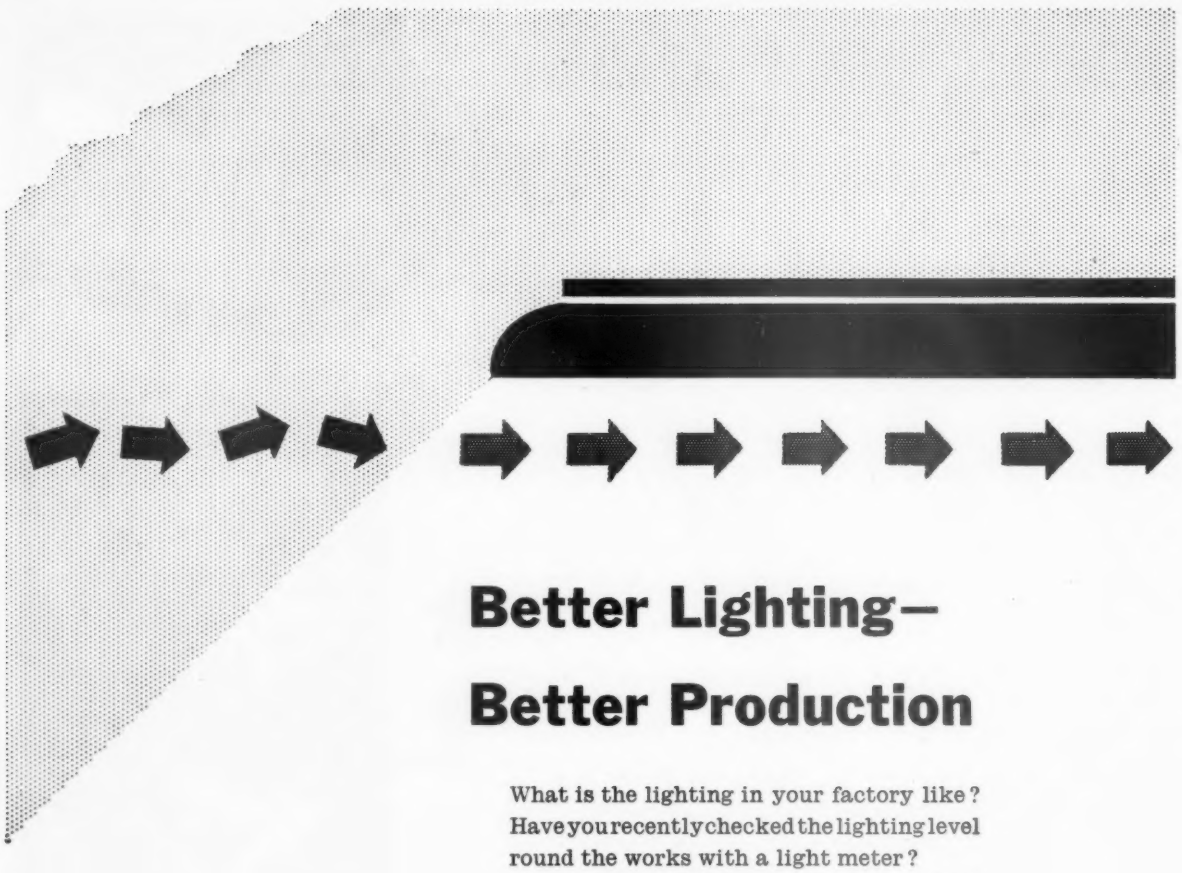

Better Lighting—
Better Production

What is the lighting in your factory like? Have you recently checked the lighting level round the works with a light meter?

The *right* lighting has a significant effect on the speed and accuracy of production. When its strength, position and type is suitable for each job the craftsman can give full play to his skill, and the works engineer can do full justice to his shop.

Good lighting is only one of the many ways in which electricity is playing a vital part in the drive for higher productivity.

Electricity for Productivity

Ask your ELECTRICITY BOARD for advice and information, or get in touch with E.D.A. They can lend you, without charge, films about the uses of electricity in industry. E.D.A. are also publishing a series of books on Electricity and Productivity. Titles now available are: Electric Motors and Controls, Higher Production, Lighting in Industry, Materials Handling, and Resistance Heating. Price 8/3, or 9/- post free.

Issued by the
British Electrical Development Association
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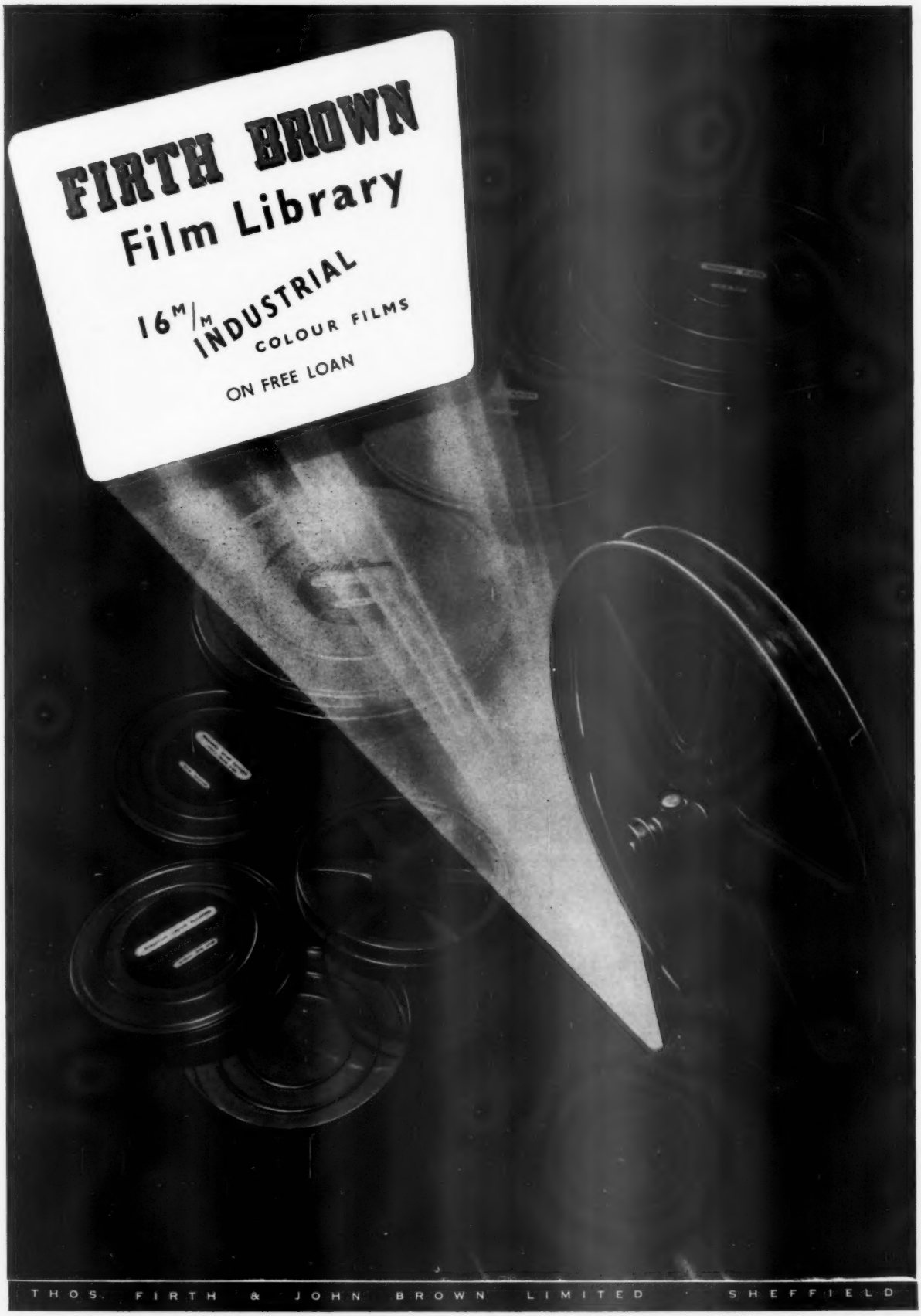
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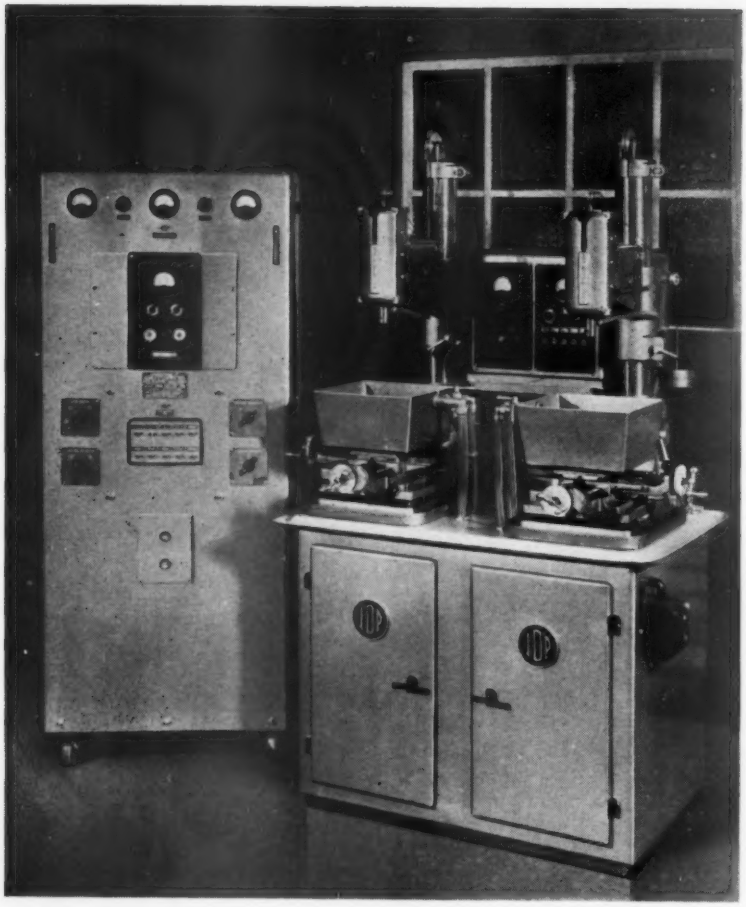


For production of all types of dies and form tools.

The leading manufacturers of spark machining equipment in the world, have pleasure in announcing their latest

SPARCATRON Mk. II Model

With double head.

This addition to the Sparcatron range of machines for spark machining has been produced as the result of requests for an equipment for use with large section electrodes to be operated to very close limits, and can be supplied with two heads as illustrated, or with a single head.

The twin head model can be easily worked by one operator, and the heads operated separately, so that production per man hour is doubled.

A further two or more heads may be used in conjunction with the main control unit in some circumstances.

Manufactured by:

IMPREGNATED DIAMOND PRODUCTS LTD., GLOUCESTER, ENGLAND

TELEPHONE 21164 (3 LINES) TELEGRAMS IMPREG GLOUCESTER

Gauthier

Precision Automatic Model 1.h.

FOR RAPID PRODUCTION AND CLOSE ACCURACY

Largest dia. of component (Brass) ..	.275″
Largest dia. of component (Steel) ..	.236″
Maximum length of component ..	2.952″
Spindle speeds	1980—6000 R.P.M.

Precision Gear Hobbing Machine Model W.1.

MODERN DESIGN · EASY SETTING PRECISION WITH EFFICIENCY...

Maximum gear dia.	2.480″
Maximum face width	1.575″
Maximum pitch module	.8
8 cutter spindle speeds from 500—2500 R.P.M.	

Precision Automatic Model G.12.

VERSATILE IN USE · SIMPLE IN SETTING · ELECTRICAL CONTROL

Largest dia. of component, round	12.7 m/m.
Maximum length of component	140 m/m.
Working spindle speeds	1000—8000 R.P.M.

Selson MACHINE TOOLS

The Selson Machine Tool Co. Ltd

CUNARD WORKS, CHASE ROAD, NORTH ACTON, LONDON, N.W.10

Telephone: Elgar 4000 (10 lines) Telegrams: Selsomachi, London

THE 600 GROUP

Do not disturb

Can two hands do the work of four — or six — or more? Does increased production necessarily require more man-power?
Can life be made more attractive and easy for my present operators?
These are questions often asked by harassed production executives in practically every industry, and the lucky ones find the answers they want in Enots several booklets explaining in fullest detail the advantages of controlled air power in the factory.
Automate with Enots and British Bellows Pneumatic Equipment NOW! Our technical representatives are ready to advise you on your particular problems — and without the slightest obligation of course.

Two short films "Production Miracles" and "Operation Push Button" produced by the Bellows Corporation of Akron, Ohio, U.S.A., and illustrating the application of pneumatic devices as aids to increased production and efficiency, are available for exhibition on application to Benton and Stone Limited.

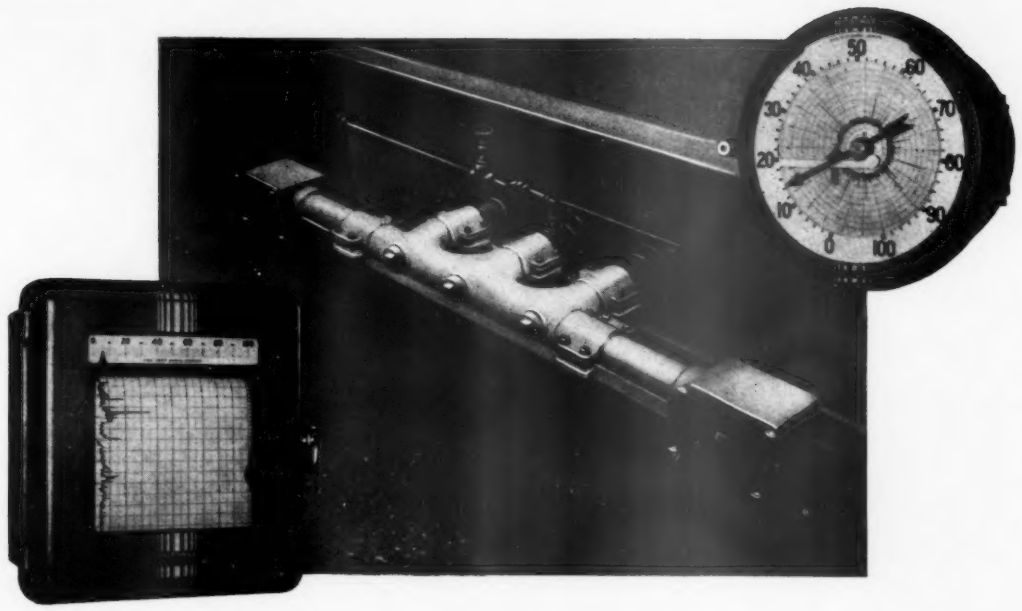
Enots and BRITISH BELLOWS

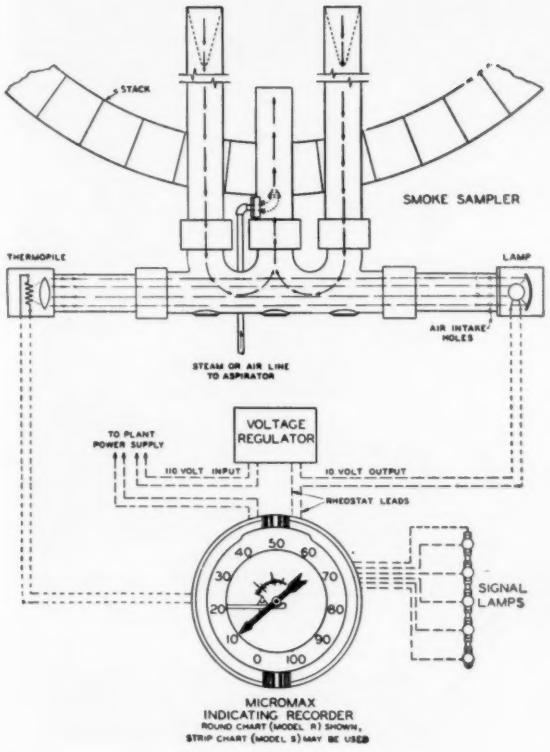
PNEUMATIC EQUIPMENT

BENTON & STONE LTD., ASTON BROOK ST., BIRMINGHAM 6, ENGLAND

See our Exhibits at The International Machine Tool Exhibition 1956

June 22–July 6, Olympia, London





Smog!

Leeds Northrup Smoke Density Recorder

Drastic reduction and eventual elimination of the emission of smoke into atmosphere is a vital necessity. It is a menace to health, and economically, a sign of poor combustion and therefore waste. Leeds Northrup Smoke Recorder equipment is inserted in one side of the stack only. Smoke is drawn in through the outer arms of the sampling unit and flows out through the central arm clear of lens and thermopile unit. Radiation from the lamp, which is fed from a constant voltage unit, falls on the thermopile, the amount of illumination varying according to the density of smoke passing through the sampling unit. Thermopile output—the measure of smoke density—is fed to a potentiometric recorder.

See Smoke before it leaves the Stack

Send for a descriptive leaflet to Dept., P.N.

INTEGRA, LEEDS & NORTHRUP LTD.
183, BROAD STREET, BIRMINGHAM, 15
Telephone: MIDLAND 1453/4 Telegrams: FLOMETER, BIRMINGHAM

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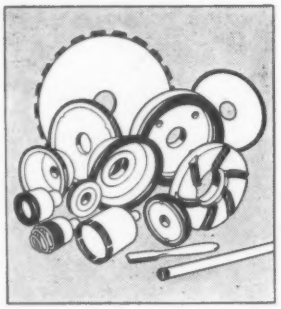
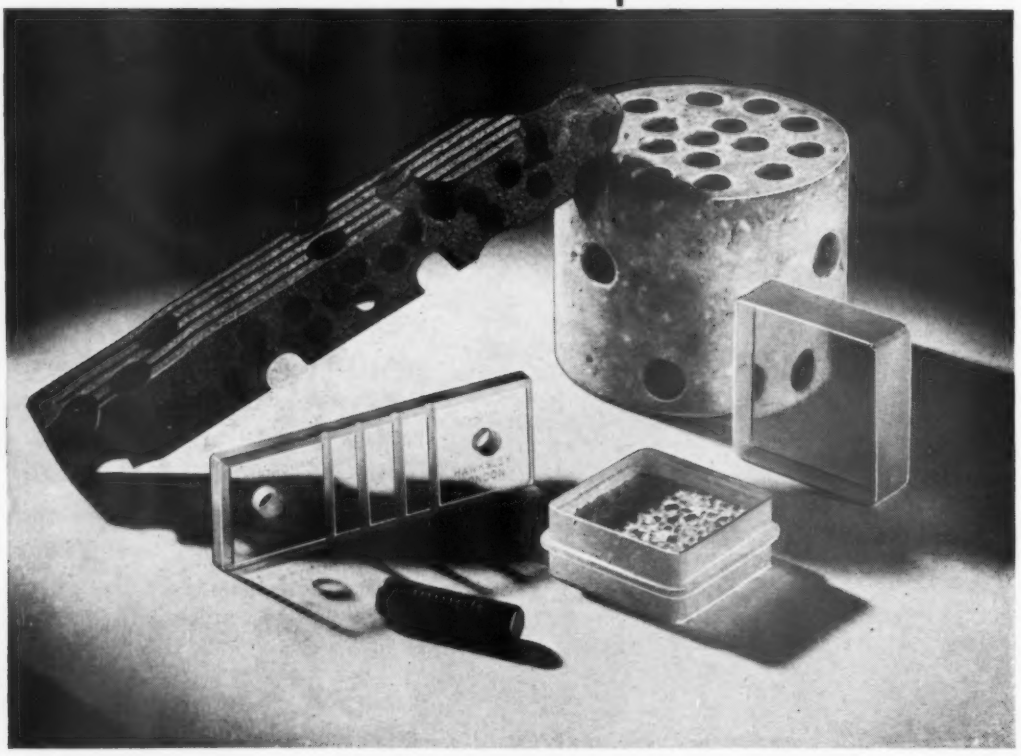
NEVEN *Diamond* TOOLS



cut, drill or grind any hard material



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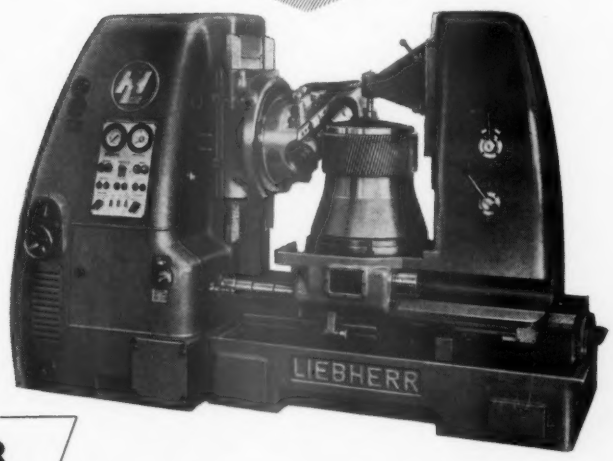
A fine new machine



LIEBHERR

GEAR HOBBING MACHINES

This Liebherr Gear-hobber is new to this Country but is well known on the Continent. Its design is based on long experience, but with today's requirements and modern developments given the precedence they deserve.
Running is smooth, cuts are clean, indexing accuracy is extremely high and the machines can be used for climb or conventional hobbing. Further features include infinitely variable main drive and feed drive, compact hob head and index worm drive with a special gearing supplied as standard with a single-start worm.
4 machines are available, maximum diameters hobbed, without back stop, being 23½″, 32″, 71″ and 118″ — with back stop, 23½″, 19⅜″ 33⅜″ and 47″.
All models are push-button controlled.

SIDNEY JONES SOLE AGENTS IN THE BRITISH ISLES

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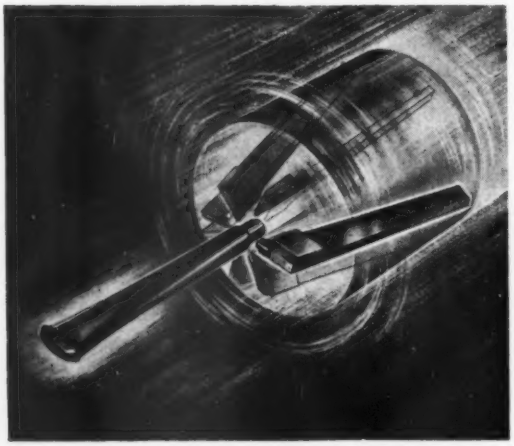

the smoker's diamond

One of the earliest production uses of shaped diamond cutting tools was developed in the French Briar Pipe manufacturing industry. In order to provide an air-tight fit between the vulcanite mouth-piece and the briar bowl stem, Diatipt "Trapping" Tools are still used to finish machine the spigot of the vulcanite component.

LM VAN MOPPES & SONS (DIAMOND TOOLS) LTD
BASINGSTOKE · HAMPSHIRE · ENGLAND

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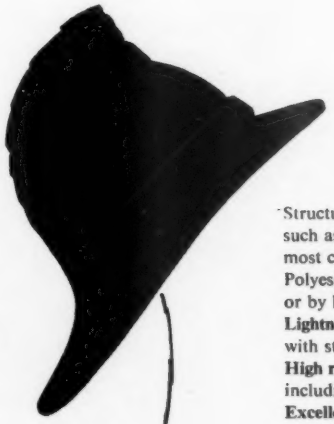
Hats off to **structural plastics**

the new lightweight material that is making such rapid headway

Already well known for their more spectacular applications, such as moulded boat hulls and motor car bodies, structural plastics offer unending economic possibilities for light, strong products of modest dimensions. Protective headgear, for instance, and many items of service or personal equipment made from structural plastics would be essentially light and yet have specific strengths comparable with steel. In these, as in structural engineering applications, wherever weight/strength problems arise or high resistance to corrosion is a prime requirement, structural mouldings may well provide the answer. Why not get in touch with B.I.P., the polyester resin people—perhaps they can help take weight off *your* mind!

Consult **B·I·P** *Services*

***B.I.P.**—makers of the highest quality polyester resins—gladly offer the full resources of their Research, Development and Design Services to manufacturers interested in the potentialities of structural plastics.*



What are **structural plastics?**

Structural plastics consist of a reinforcing agent, such as glass fibre, bonded with a synthetic resin, most commonly a polyester type resin.
Polyester/glass fibre mouldings can be made either mechanically or by hand fabrication and their essential characteristics are . . .
Lightness combined with strength—specific strengths comparable with steel.
High resistance to corrosion by a wide range of chemicals, including some acids, and to all but excessive heat.
Excellent electrical properties—high breakdown and low power factor, combined with good insulating and non-tracking properties.
Unlimited colour possibilities—in opaque or translucent shades.

B·I·P Chemicals Ltd Oldbury, Birmingham · *Telephone:* Broadwell 2061

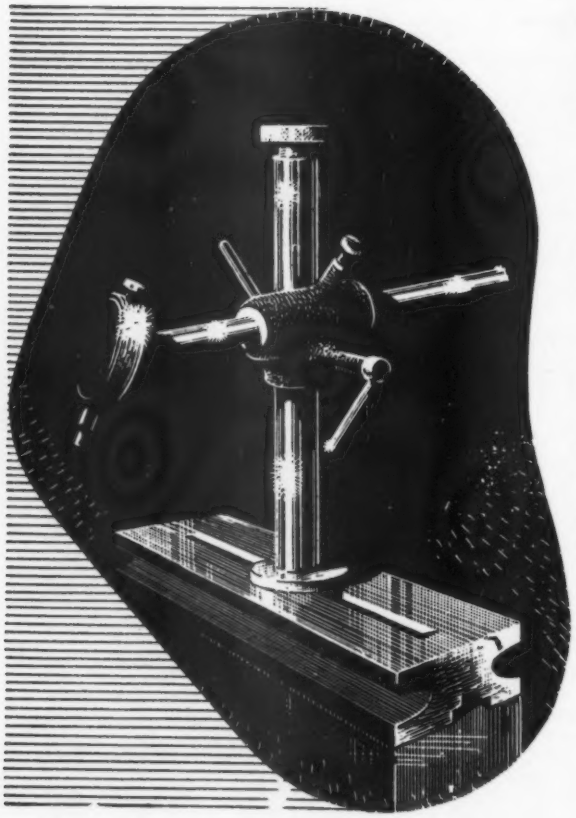
LONDON: 1 Argyll Street, London, W.1 · *Telephone:* Gerrard 7971

MANCHESTER: 79 Mosley Street, Manchester 2 · *Telephone:* Central 9014

We welcome your enquiries

FOR ALL KINDS OF

JIGS · FIXTURES & GAUGES



PRESS TOOLS · MOULDS AND SPECIAL PURPOSE MACHINES

Our commitments are heavy but we welcome an opportunity to study your requirements for inclusion in our production programme where possible.

Up-to-date shops specially laid out and equipped for making, on a production basis, every type of precision ground gauges; limit snap, form, calliper, taper and special purpose gauge, as well as jigs and fixtures of all kinds, press tools moulds and special purpose machines. Highest class workmanship and accuracy guaranteed.

Guaranteed
Precision
Accuracy

G.P.A.

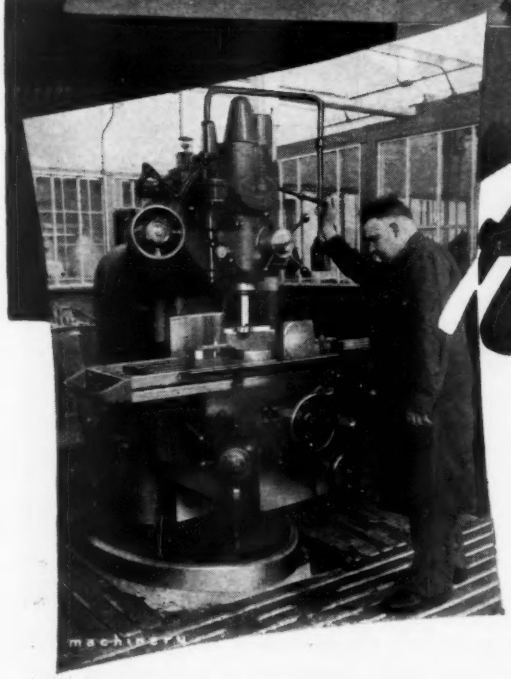
G.P.A. TOOLS & GAUGES LIMITED

HARPER ROAD · WYTHENSHAWE · MANCHESTER

Phone:- **WYTHENSHAWE 2215**

Grams: **PNEUTOOLS, PHONE**

FOR HEAVY DUTY DIE AND TOOL WORK



34" Archdale

VERTICAL MILLING MACHINE

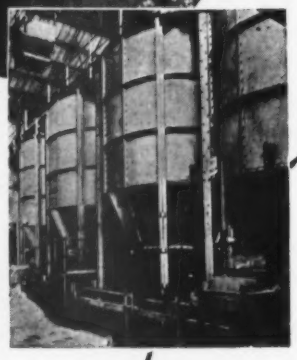
with combined sliding and swivelling head . . .

This massive, powerful and versatile machine, with its sliding and swivelling head, makes light of heavy duty die and tool work at the Enfield Cycle Co., Ltd., Redditch. Table has reversible automatic feeds and quick-power traverse in all three directions. Speeds and feeds changed from front of machine. Direct reading dials. Twelve speeds from 29/520 r.p.m., or alternatively 36/638 r.p.m. Twelve feeds, $\frac{3}{8}$in. to 20in. per minute. Quick and fine hand adjustment to spindle, which swivels through 90°. Table working surface 53in. × 14$\frac{1}{2}$in.

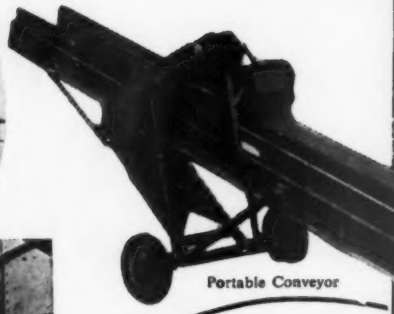
JAMES ARCHDALE & CO. LTD. BIRMINGHAM, 16

SOLE SELLING AGENTS: ALFRED HERBERT LTD., COVENTRY

Complete Telpher Installations



Sand Storage Hoppers



Portable Conveyor

Pallet Conveyors

Something worth knowing

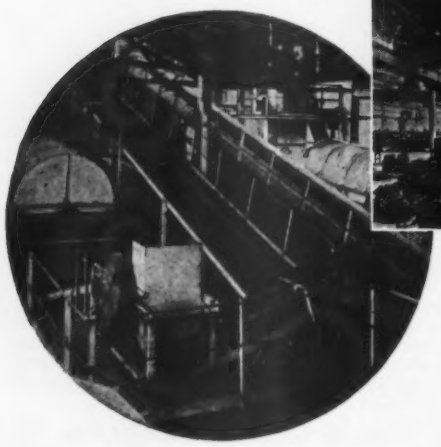
Paterson Hughes Mechanical Handling Systems are used in almost every industry in the world.

Portable Sack Elevator

Roller Conveyor Systems

Slat Conveyors

Overhead Travelling Cranes



Sand Conditioning Plant

Overhead Chain Conveyors

PATERSON HUGHES
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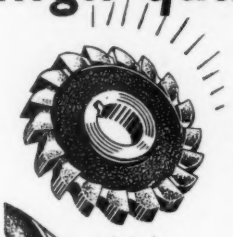
SOUTH AFRICA · PATERSON HUGHES ENGINEERING S.A. (Pty) Ltd., P.O. Box 811 JOHANNESBURG, S.A

MECHANICAL HANDLING ENGINEERS AND CRANE MAKERS

B.S.A ids to Production

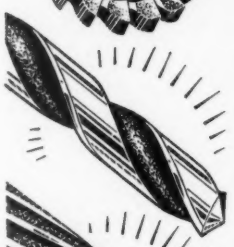
TRADE MARKS B.S.A

high quality tools for all classes of work



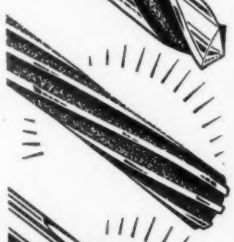
MILLING CUTTERS

An extremely wide range. H.S.S. (and Cast, at lower cost). All the most generally used sizes and types. Super-cut, for heavy-duty milling, have specially designed teeth for extra strength. Form relieved and special cutters supplied.



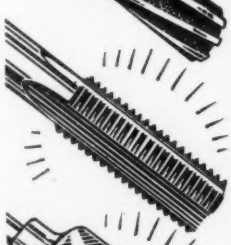
TWIST DRILLS

Specially treated for long-life. Materials of only the highest grade are used in their manufacture. B.S.A. drills definitely reduce hole costs. H.S.S., Carbon steel, and special types for various materials.



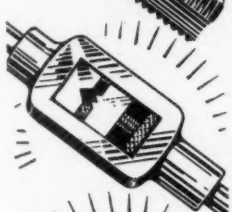
REAMERS

All standard types and sizes available in H.S.S., including counterbores, adjustable reamers, shell reamers and arbors. Specialities include a Super-finish reamer for heat-treated steels, and a combined drill-reamer—a real time saver.



TAPS

A complete coverage of standard H.S.S. ground thread, and carbon steel cut-thread and ground-thread. Sizes and types outside the usual range can be supplied, including taps with spiral points or spiral flutes, at special prices.

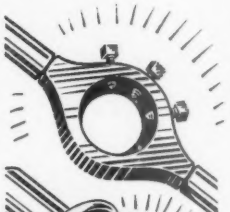


TAP WRENCHES

These are of the adjustable type, Nos. 1 to 4, covering taps from $\frac{1}{16}$in. to $1\frac{3}{4}$in. and Services type B.B.: $\frac{3}{8}$in. to 1in., C.C.: $\frac{1}{4}$in. to $\frac{3}{4}$in. Carefully treated, well finished, extremely durable.

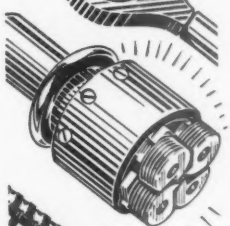
SCREWING DIES

Carbon steel, circular adjustable type: plain, parallel and taper, for British and American threads and Metric sizes. Also a complete range of carbon steel hexagon die nuts. Of consistent quality and uniformity.



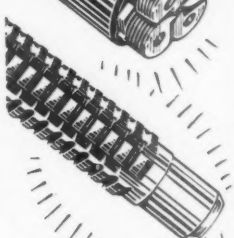
DIE STOCKS

For circular dies from $\frac{13}{16}$in. to $2\frac{1}{4}$in. dia. Made to the same high standards as other items in the B.S.A. range of screwing equipment. Also screwing sets, thread rolling dies, tap extractors and—



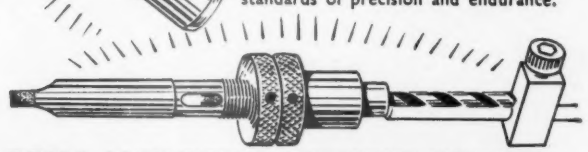
DIEHEADS

B.S.A. NAMCO—simple in construction, easy to adjust. Circular chasers ensure extreme accuracy of thread form and long life. They can be ground and re-ground through a full 270 degrees of their circumference.



BROACHES

Scientifically processed for extra performance. B.S.A. Tools' Broach Division has the capacity and ability for designing and manufacturing every size and type of broach, each to the highest standards of precision and endurance.



DRILL HOLDER & SETTING GAUGE

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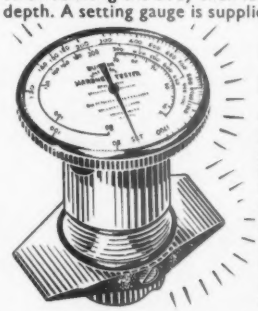

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A lightweight, accurate, universal, direct-reading hardness tester. V.P.N., Brinell and Rockwell 'C' hardness values (B.S.I. 860) are marked in contrasting colours on its large easily-read dial. Pressure on the grip lowers the diamond indentor to the test piece. Further pressure causes the hardness value to be registered. Penetration in soft metal is only 0.005in. Supplied in a handsome case complete with servicing kit.

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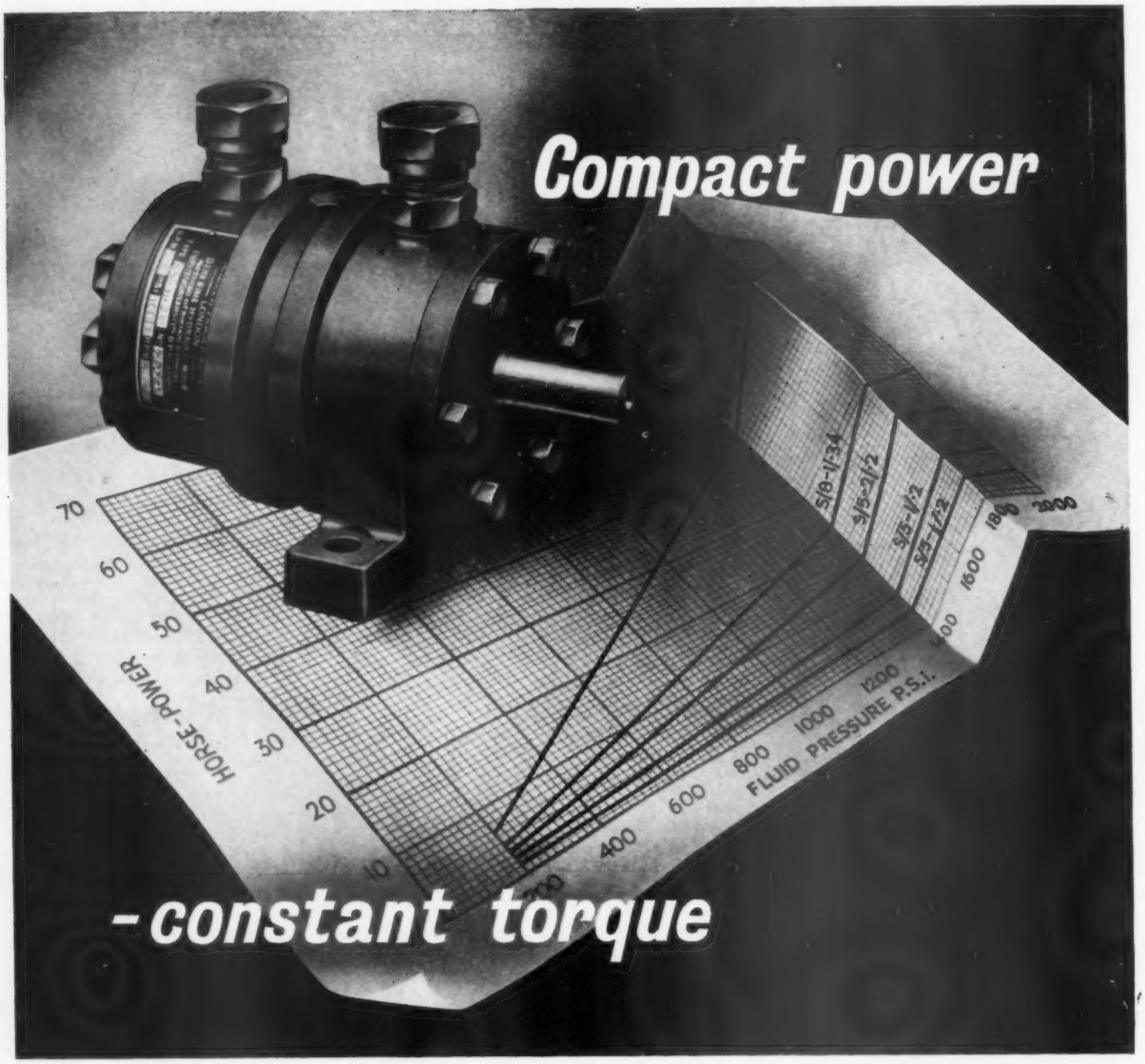
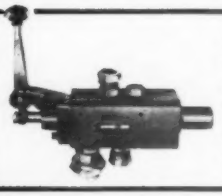


Constant and full load starting torque is only one of the features of this outstanding hydraulic motor. It introduces high efficiency at low speeds and maintains it throughout the range, and provides exceptionally smooth transmission of power for a widely varied number of applications. Capable of rotation in both directions.

The smooth and vibrationless operation of the Motor is also a feature of the Deri-Sine Hydraulic Pump, a rotary displacement pump of high volumetric efficiency, which is essential to the power circuit.

An output of up to 4,000 lb./in. torque is available in a range of four basic sizes which incorporate variations in stator and rotor dimensions.



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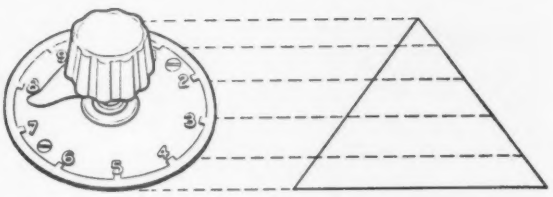

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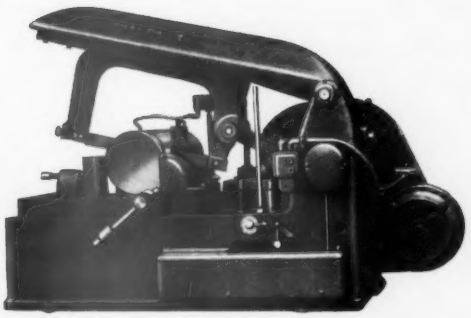

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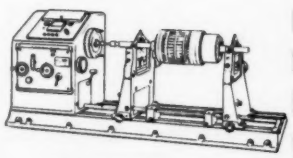
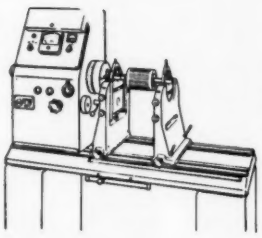


Model UA. for components from 2.2 lbs. to 22,000 lbs.



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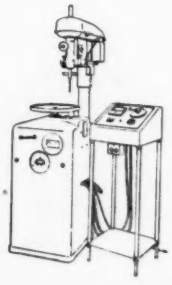

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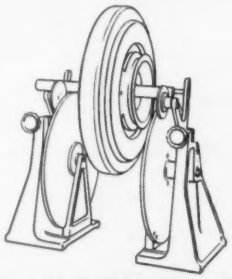

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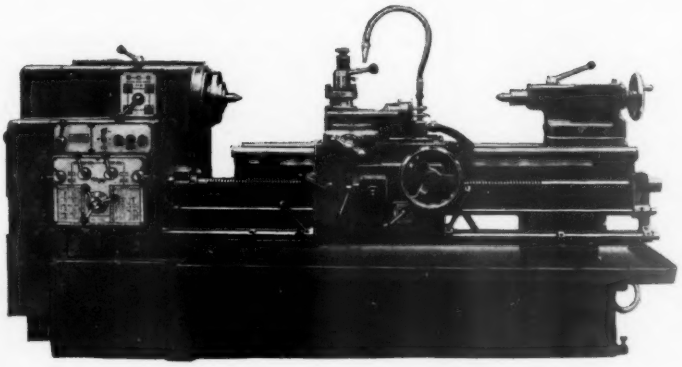
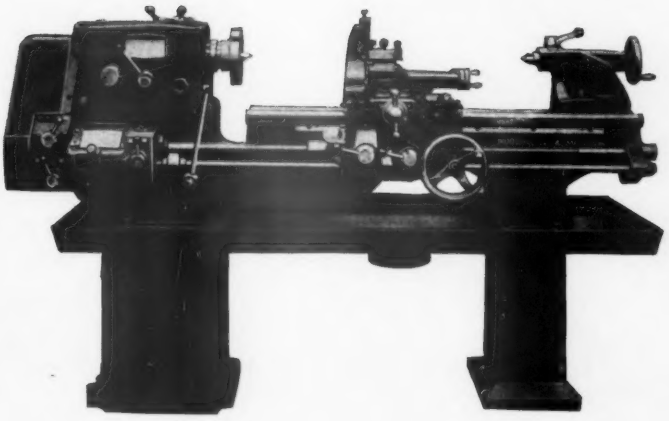


Model '85'

8½" centre lathe

Model '70' junior

7" centre lathe



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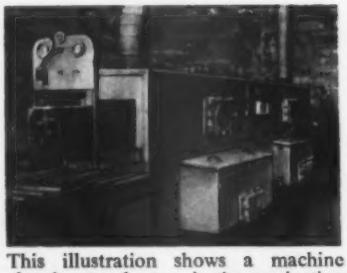
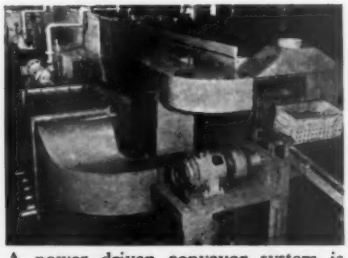


This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.



A power driven conveyor system is employed with this cleaning machine for ball bearings.

Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

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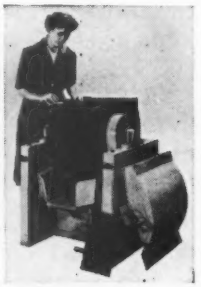

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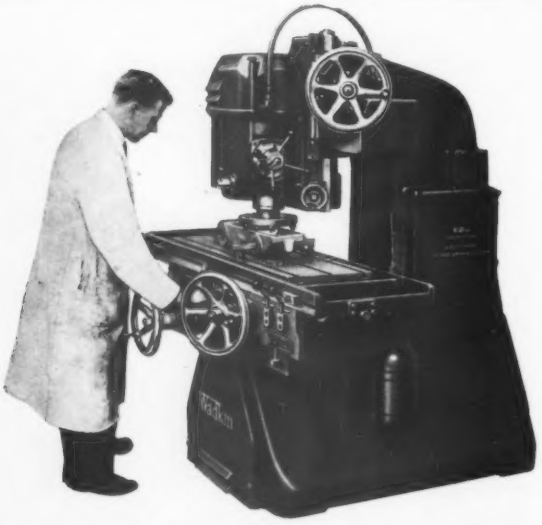

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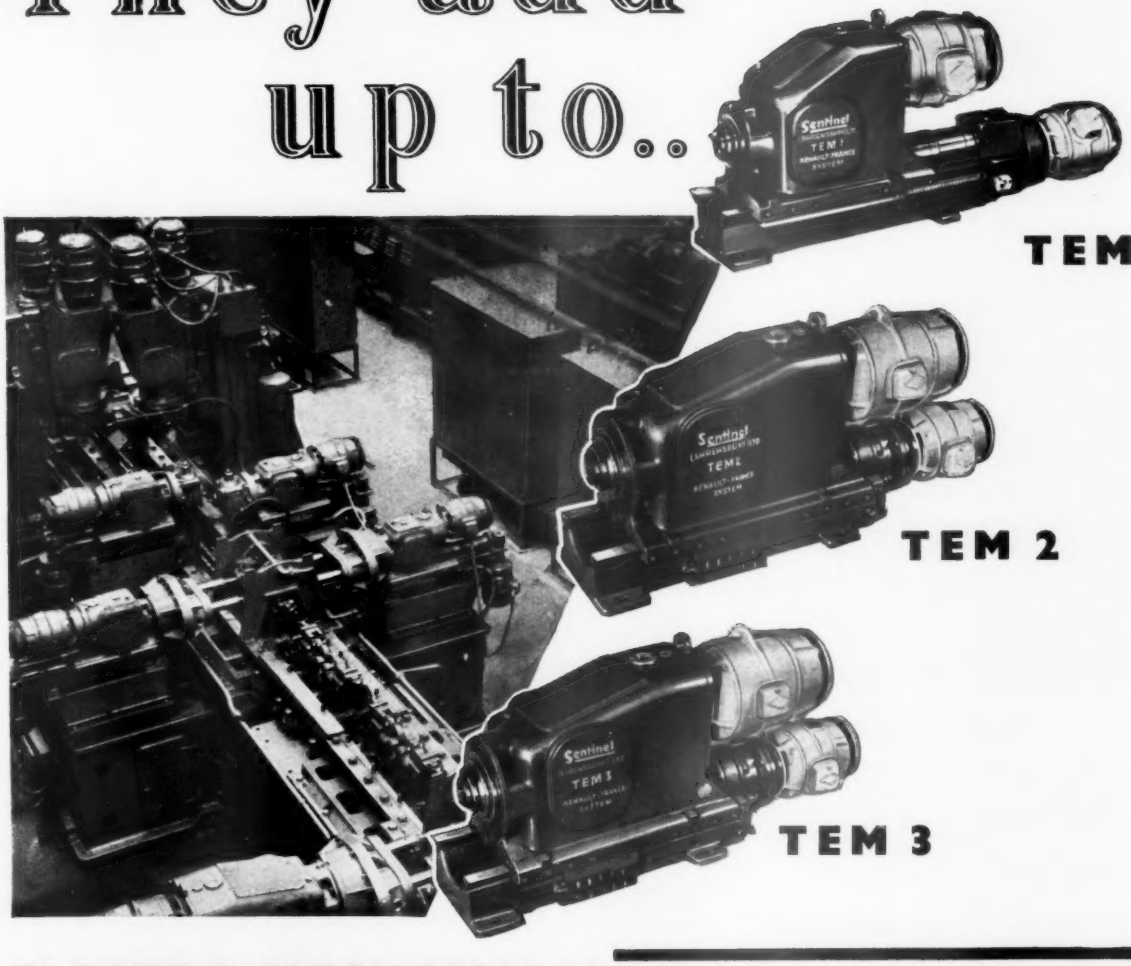

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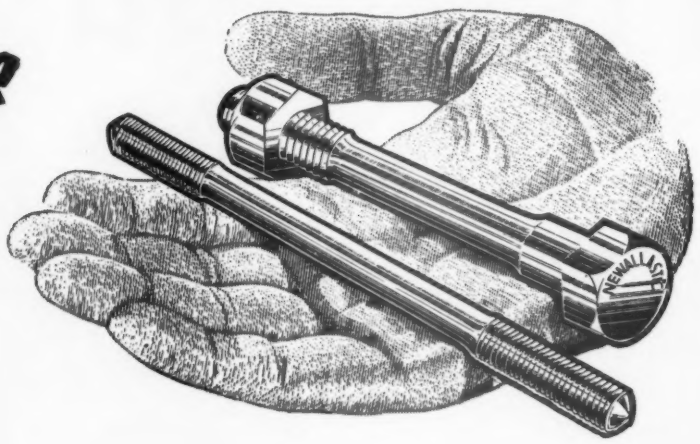

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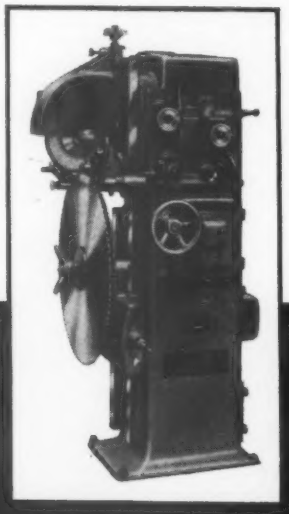

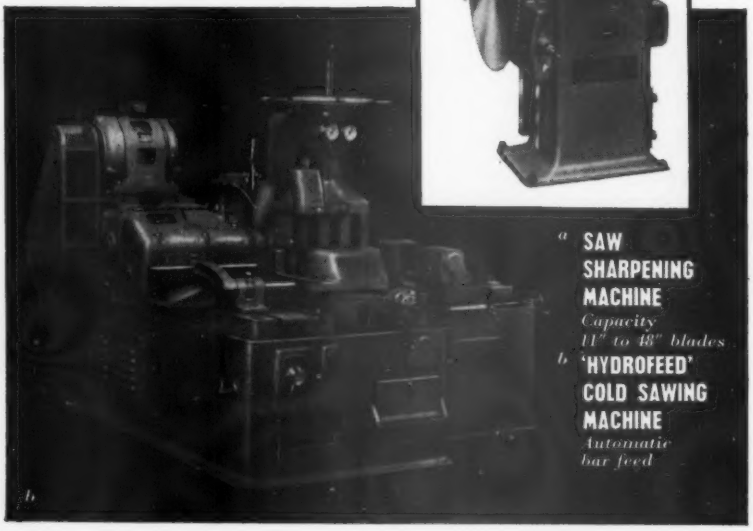

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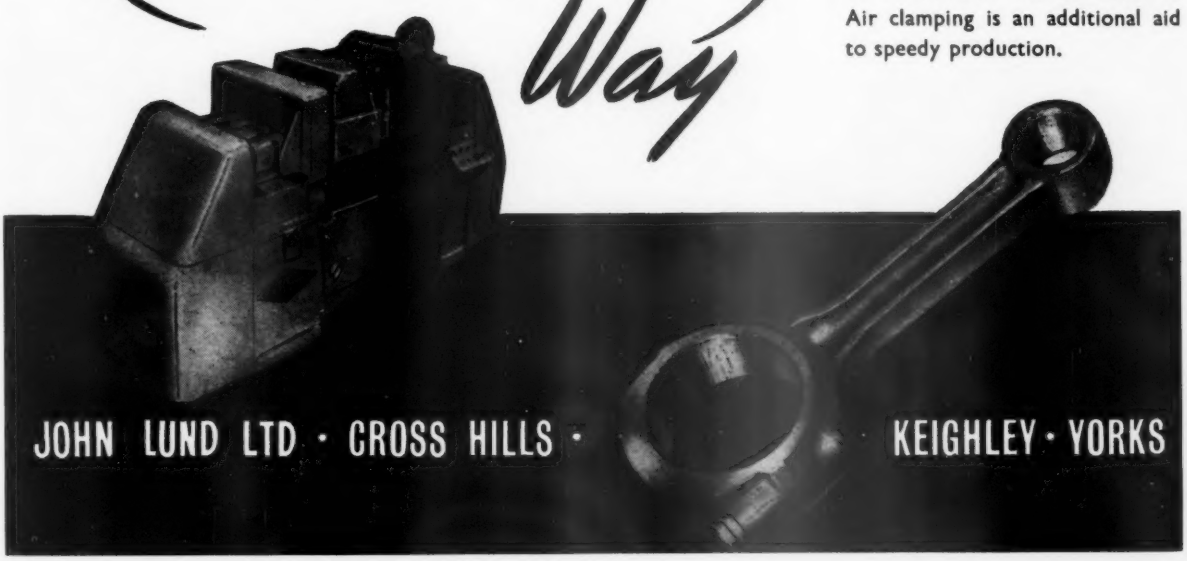

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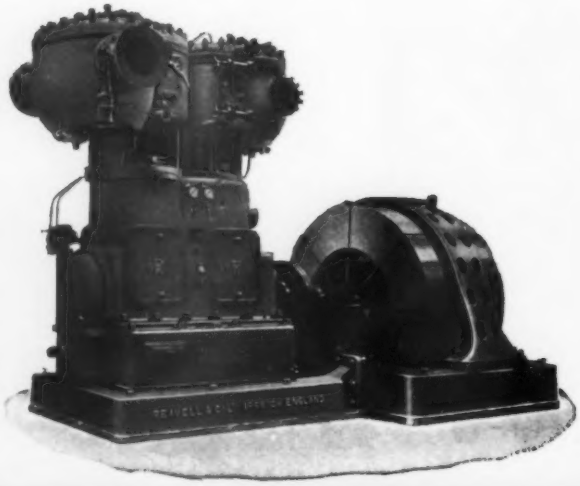

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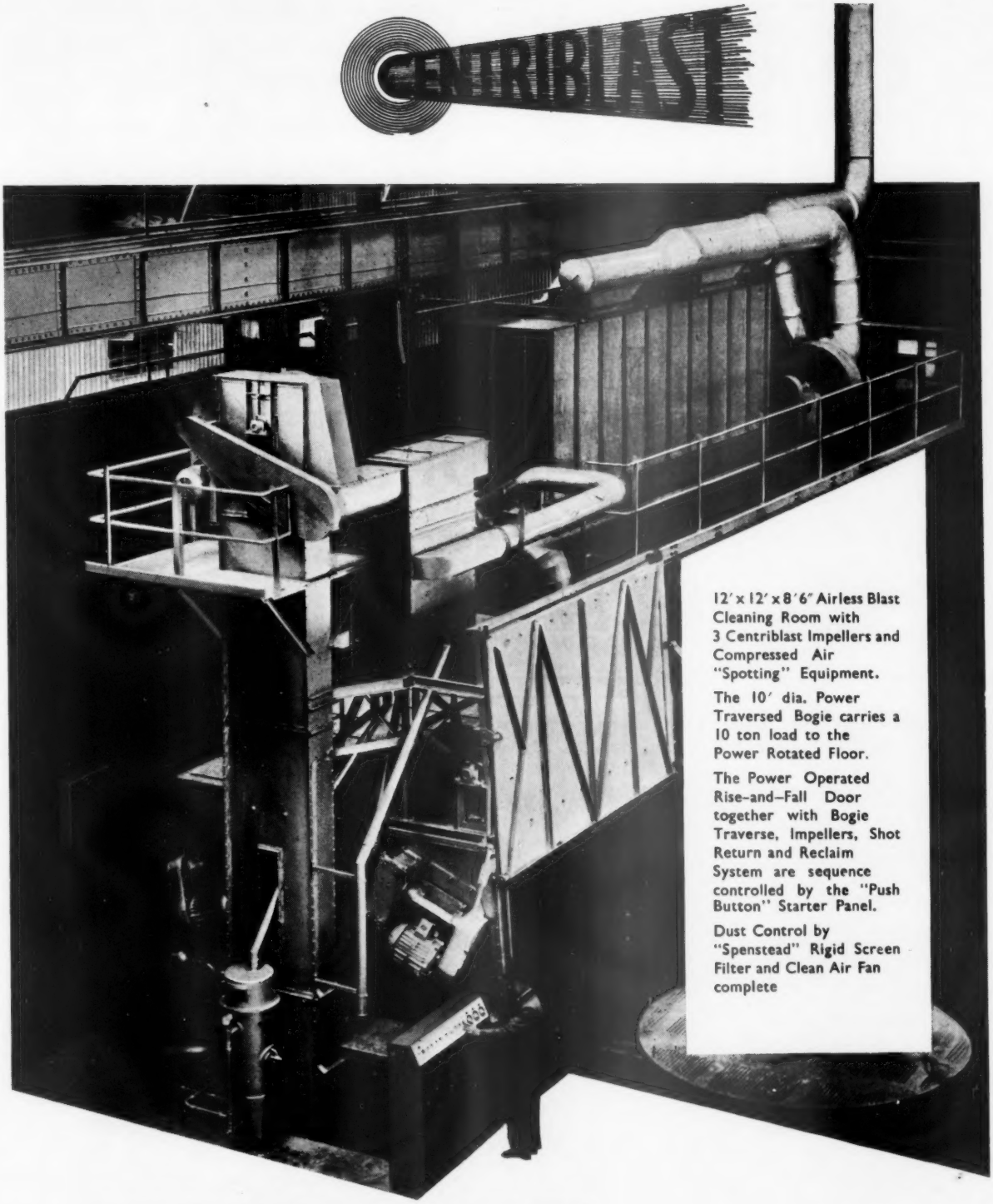

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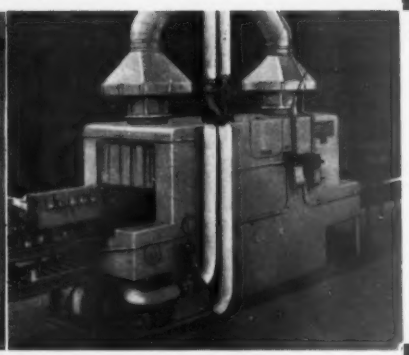

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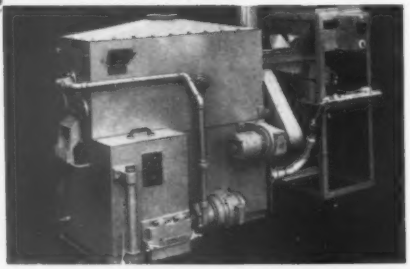

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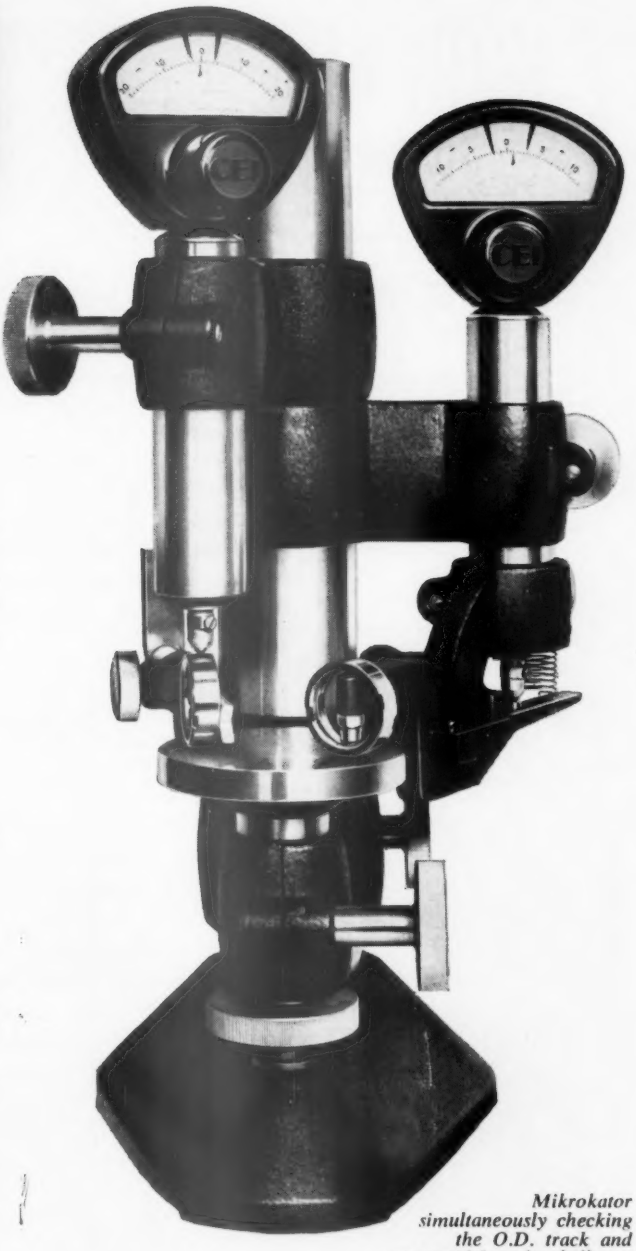

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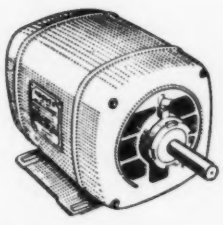

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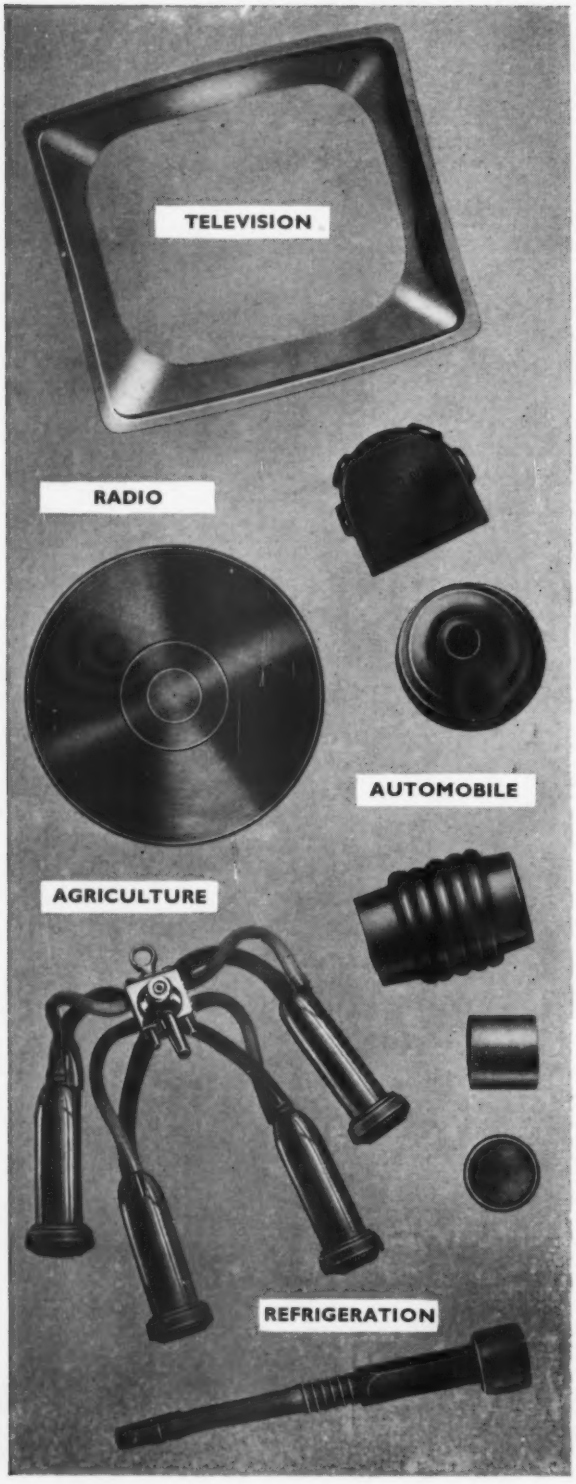

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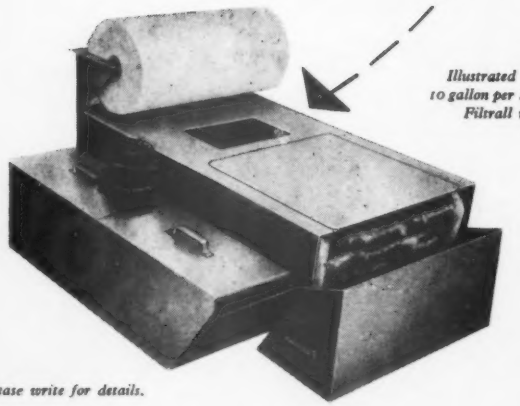

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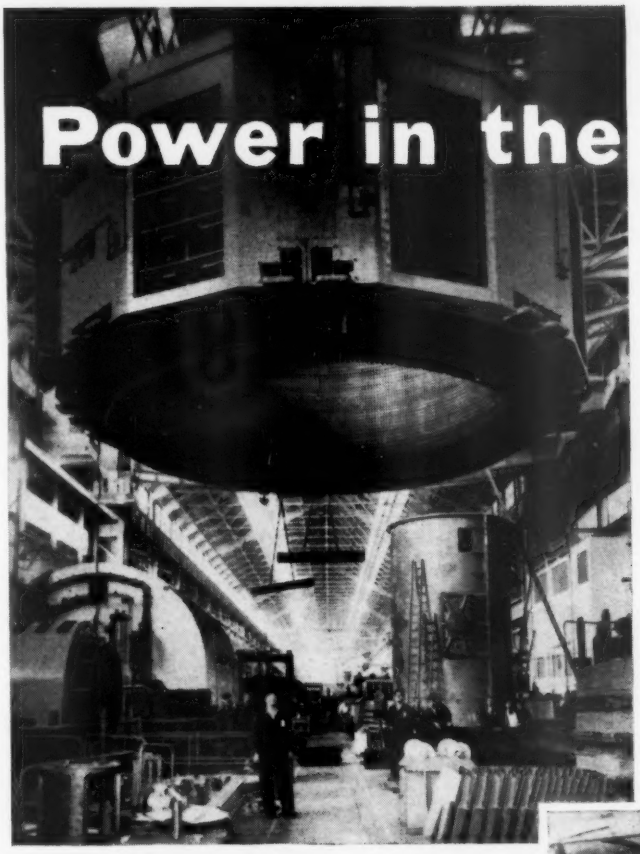

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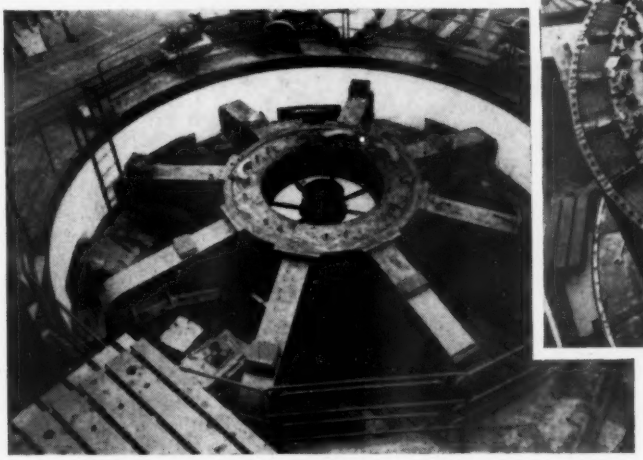

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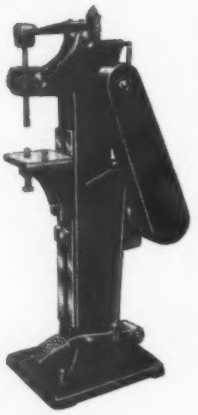

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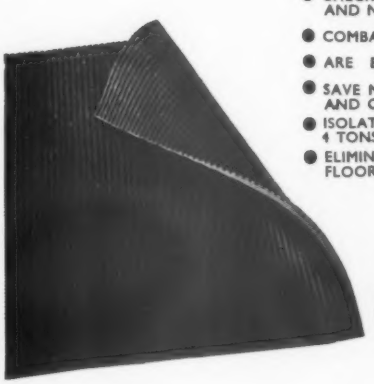

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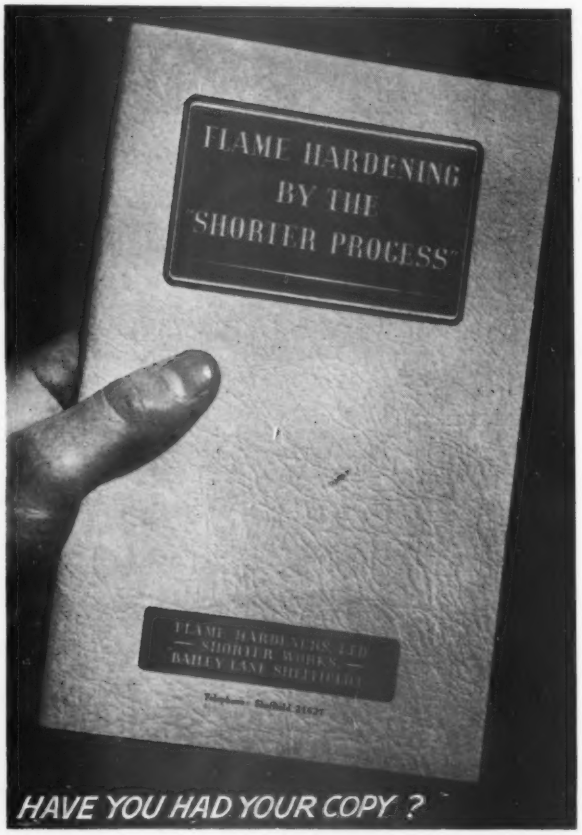

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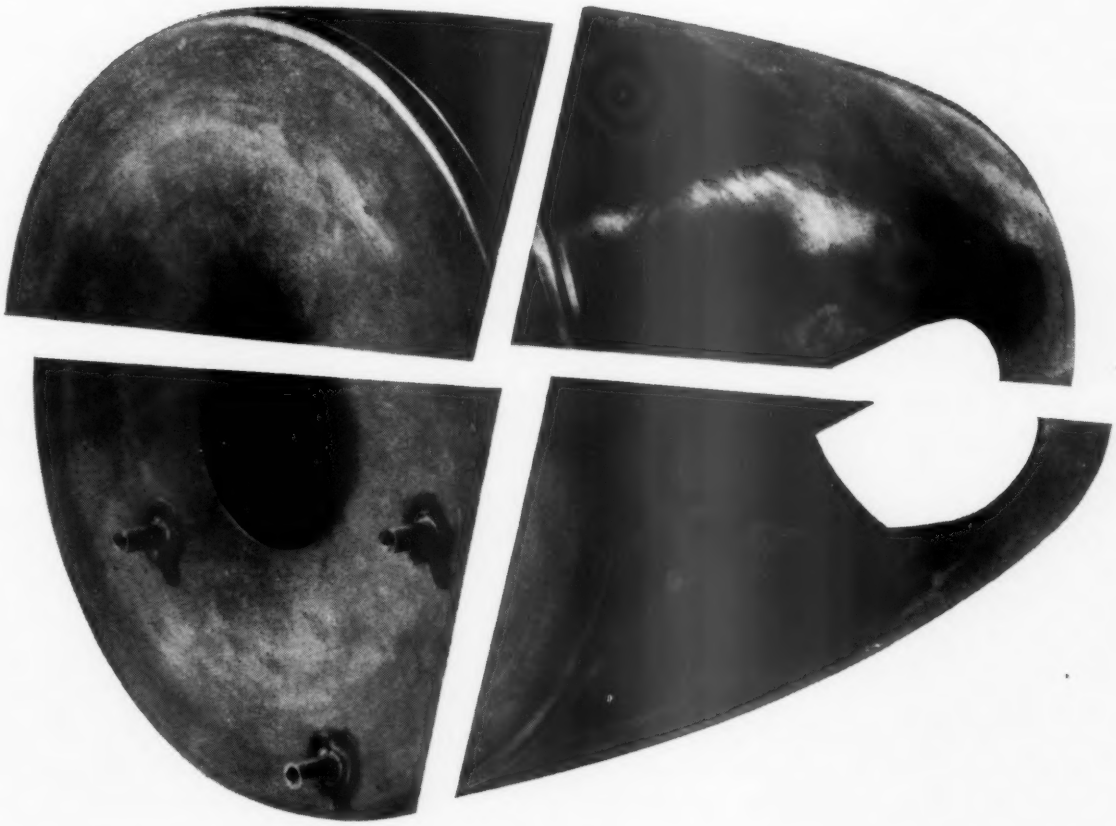
Give you three guesses

THIS IS:—

(A) ***Part of a vacuum cleaner*** **(B)** ***A coffee percolator*** **(C)** ***An artificial satellite***



The correct answer is B. This picture at least shows plainly one of the great advantages to be gained by Crompton Parkinson Stud Welding. The coffee percolator is an example of re-designing with stud welding specifically in view. The three brass bosses which secure the electrical mechanism to the percolator are cleanly welded on to the base and there is no perforation of the metal or risk of subsequent leakage. In many branches of light and heavy industry Crompton Parkinson Stud Welding is helping to speed production and improve design. Let us give you a demonstration on your own premises and show you how simple and inexpensive it is.

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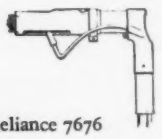

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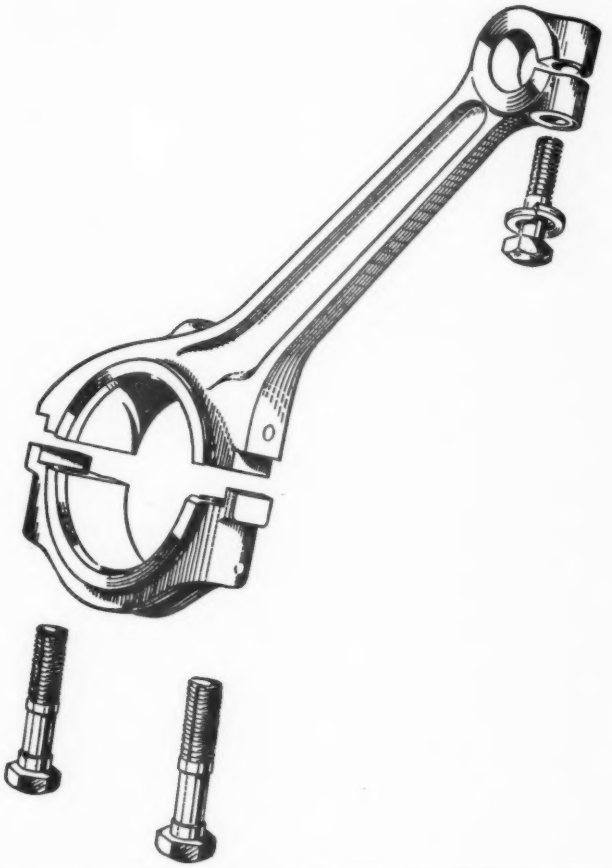

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